JC02 Rec'd PCT/PTO 0 9 APR 2001

FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
112740-169

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/807232

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE99/03227	06 October 1999	09 October 1998

TITLE OF INVENTION
OPTICAL FILTER, ADJUSTABLE ADD-DROP-CONTINUE MODULE AND CIRCUIT FOR BUNDLED CROSS-CONNECTION FUNCTIONALITY

APPLICANT(S) FOR DO/EO/US
Dr. Harald Bock et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☒ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☒ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☒ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Submission of Drawings Figures 1-13 on seven sheets

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09/807232	PCT/DE99/03227	112740-169

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

	CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1,000.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO **$860.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	19 - 20 =	0	x $18.00	**$0.00**	
Independent claims	9 - 3 =	6	x $80.00	**$480.00**	
Multiple Dependent Claims (check if applicable) .			☐	**$0.00**	
	TOTAL OF ABOVE CALCULATIONS =			**$1,340.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)** .			☐	**$0.00**	
	SUBTOTAL =			**$1,340.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).			+	**$0.00**	
	TOTAL NATIONAL FEE =			**$1,340.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**			☐	**$0.00**	
	TOTAL FEES ENCLOSED =			**$1,340.00**	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$1,340.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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SIGNATURE

William E. Vaughan
NAME

39,056
REGISTRATION NUMBER

April 9, 2001
DATE

BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

PRELIMINARY AMENDMENT

APPLICANTS:	Dr. Harald Bock et al.	DOCKET NO: 112740-169
SERIAL NO:		GROUP ART UNIT:
		EXAMINER:
INTERNATIONAL APPLICATION NO:		PCT/DE99/03227
INTERNATIONAL FILING DATE:		06 October 1999
INVENTION:	OPTICAL FILTER, ADJUSTABLE ADD-DROP-CONTINUE MODULE AND CIRCUIT FOR BUNDLED CROSS-CONNECTION FUNCTIONALITY	

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

In the Specification:

Please replace the Specification of the present application, including the Abstract, with the following Substitute Specification:

SPECIFICATION

TITLE

OPTICAL FILTER, ADJUSTABLE ADD-DROP-CONTINUE MODULE AND CIRCUIT FOR BUNDLED CROSS-CONNECT FUNCTIONALITY

BACKGROUND OF THE INVENTION

Field of the Invention

BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
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OPTICAL FILTER, ADJUSTABLE ADD-DROP-CONTINUE MODULE AND CIRCUIT FOR BUNDLED CROSS-CONNECT FUNCTIONALITY

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a tunable optical filter, to an add-drop-continue module which is produced using this filter, to an add-drop-continue device and to a circuit for bundled cross-connect functionality.

Description of the Prior Art

In order to ensure minimal interference during signal transmission, optical wavelength multiplex networks (WDM networks) are redundantly designed. Ring structures are often provided. At ~~a~~ junctions between different rings, "drop-and-continue" functions are implemented; i.e., the signal is split and is both forwarded through the original ring and transferred into the new ring. For purely optical production of a drop-and-continue function, it is possible to use wavelength demultiplexers, optical switches and wavelength multiplexers.

For the production of add-drop functions, modules from the company High Wave Technologies are known~~,~~ which consist of two circulators with interposed tunable filters. In the event of tuning due to a configurational change, however, the retuning of one WDM channel generally interferes with the signals of other WDM channels. These modules are not intended for drop-and-continue functions. It is, however, conceivable to supplement this module with splitters and switches~~,~~ in order to produce the drop-and-continue function.

Figure 1 represents such an "add-drop-continue module". It consists of a splitter SP~~,~~ which divides the optical signal into two signals of roughly equal strength. One component is fed via two circulators having a tunable filter connected in between. In order to produce the drop-and-continue function, one signal component D_k is branched off via the first circulator and the other signal component C_k is forwarded via an optical switch SW (the switch position which is represented).

In the case of an add-drop function, one signal component D_k is likewise branched off, but a new signal A_k having the same wavelength is simultaneously inserted via the second circulator ZI2. Owing to the use of the optical splitter, the module has in principle an attenuation of at least 3 dB.

Depending on the number of add-drop functions, the aforementioned add-drop element is multiply connected in series, so that the attenuation is further increased significantly.

The cross-connect functionality in optical multi-wavelength multiplex systems (WDM) is needed so that a specific wavelength signal of an incoming multi-wavelength signal can be distributed in any desired direction.

"WDM Gridconnect - ein transparentes faseroptisches Kommunikationsnetz mit Faser- und Wellenlängenmultiplex" [WDM grid-connect - a transparent fiber-optic communications network having fiber and wavelength multiplex] by Hubert Anton Jäger, published by Hartung-Gorre-Verlag, Constance [Germany] 1998 describes a standard optical cross-connect (OXC). Such an optical cross-connect (OXC) having optical n x n space-switching subunits with n incoming bidirectional multi-wavelength signals, each having k wavelengths, is represented in Figure 9. In this case, the optical multi-wavelength signal is decomposed via optical wavelength demultiplexers DMUX into k single-frequency signals which are subsequently switched to any desired output of the space-switching subunit by using optical space-switching subunits of dimension n x n. The single-frequency signals coming together from the outputs of the space-switching subunits are coupled and forwarded via a multiplexer MUX.

A disadvantage with this is the large outlay on equipment which is incurred when making these optical cross-connects (OXC). A circuit having, for example, 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors needs 64 space-switching subunits of dimension 4 x 4. Furthermore, 64 fiber-optic connections to the corresponding space-switching subunits of dimension n x n have to be installed per multiplexer MUX and demultiplexer DMUX, respectively, plus the same number again from the space-switching subunits to the demultiplexers DMUX or multiplexers MUX on the other side.

JP 1 023 479/US 5 963 685 describes an add-drop module which contains a number of reflection filters whose frequencies can be adjusted by mechanical pressure and changing the temperature.

The patent US 5,707,375 likewise specifies an add-drop device whose filters have different and mutually asymmetric edges. By tuning the filters in terms of wavelength, it is possible to obtain complete transmission, complete reflection or partial transmission and reflection. In this solution, it is necessary to have double the number of filters and adjustment devices. However, readjustment of the wavelength during operation leads to interference with the other signals.

The European patent application EP 0854 378 A2 describes a thermal-optical component which has a splitter and a tunable grating filter. The arrangement operates as an optical switch and can be used to produce add-drop functions. The patent US 5,408,319 describes an optical demultiplexer in which tuning to a specific wavelength is carried out not mechanically but by changing the temperature.

The patent application WO 98/04854 describes an add-drop module which can be tuned by heating strips or magnetoresistors.

WO 99/42893 also discloses a tunable add-drop multiplexer. In order to tune the wavelength, the refractive index of the filter material is changed, for example by heating.

The known principles are unsuitable or too elaborate for producing an add-drop-continue function.

It is an object of the present invention to propose an add-drop-continue module having little attenuation, as well as a filter which is suitable for its production and which has a variable transmission characteristic. This module is also intended to permit reconfiguration of channels without causing interference.

It is another object of the present invention to propose a circuit having cross-connect functionality which allows simple allocation of dynamically assembled multi-wavelength bundles to different conductors. It is another object

of the present invention to propose a circuit having cross-connect functionality, which permits reduced complexity of the system. In this case as well, reconfiguration of channels is intended to be made possible without causing interference.

SUMMARY OF THE INVENTION

Accordingly, there is a special advantage of the module of the present invention, and of the circuit for producing bundled cross-connect functionality, due to a filter whose frequency and attenuation can be varied. This not only makes it possible to select different channels, it also results in no optical switches being necessary for producing add-drop, drop-continue or cross-connect functions. Reconfiguration of the network can be carried out without interference to adjacent signals.

In particular, the present invention is achieved by an optical filter, wherein a device is provided for adjusting the transmission response via a deliberate temperature change. The effect achieved by adjusting the transmission response through temperature changes is that the optical filter is non-destructively reconfigurable, which has never before been possible in the case of purely optical network elements except with expensive optical circuit technology (wavelength multiplexers, wavelength demultiplexers, space-switching matrices). In contrast to standard wavelength filters, the transmission attenuation can also be adjusted in addition to the resonant wavelength in the optical filter according to the present invention.

In another preferred exemplary embodiment of the optical filter, at least two regions in an optically transparent material, which have different temperature-dependent refractive indices are essentially involved in the optical waveguiding and/or the filter action, and wherein the difference between the refractive indices is at least approximately zero at one temperature within the temperature-controllable working range. The temperature-dependent difference in refractive index between two optical materials is hence influenced by the

deliberate change of temperature. This exploitation of the thermo-optical effect to influence the quality factor of the resonance is performed by adjusting the resonant wavelength and the transmission attenuation d for this wavelength. On the grounds of conservation of energy, the reflection factor is obtained directly from the transmission response in the ideal case. Energy components which are not transmitted must necessarily be reflected. The resonant wavelength is essentially influenced by the period of the interfaces. The transmission attenuation is essentially given by (besides the grating length and the grating amplitude) the difference in refractive indices.

The optical filter according to the present invention is advantageously designed in planar technology. This facilitates integration into existing circuitry. The optical filter is furthermore preferably produced as a fiber grating. The difference in refractive index between two optical layers involved in the waveguiding is of essential importance in the case of fiber gratings as well. The principle employed here, namely to influence the transmission attenuation by a thermal refractive-index change, preferably may be used in the case of such filters as well.

An optical filter is preferably designed as a tunable band-stop filter. This facilitates the extraction of a frequency band. The latter is advantageous especially in purely optical telecommunications networks.

The tuning of the band-stop filter is preferably carried out by mechanical pressure, tension or bending. As such, the wavelength to be filtered in the optical spectrum can be selected by exposing the band-stop filter to mechanical influence.

The present invention is furthermore achieved by an add-drop-continue module having an optical filter according to the present invention, wherein the tunable optical filter is arranged between a branching device for optical signals and an insertion device. Accordingly, an add-drop-continue module can be constructed using an optical filter according to the present

invention. The signal is split in the branching device for optical signals, and one component is fed to the gate of the optical filter according to the present invention. The component to be extracted is reflected and forwarded, whereas the component to be injected is inserted by the insertion device.

In another preferred add-drop-continue module of the present invention, a number of optical filters are arranged between a branching device for optical signals and an insertion device. Though this arrangement, it is possible for a number of individually adjustable optical spectra to be extracted from the signal and, preferably, to be injected or re-extracted via multiplexers and demultiplexers, respectively.

In another preferred add-drop-continue module of the present invention, circulators are provided as the branching devices and as the insertion device. As such, the injection and extraction of the signals can be carried out using known hardware components. Triple circulators are preferably used for this, and quad circulators are even more preferably used. It is also possible to use Mach-Zehnder structures.

The objects of the present invention are preferably achieved by an add-drop-continue device, wherein a number of series-connected add-drop modules of the present invention are provided. Accordingly, it is possible to fulfill a very wide variety of circuit tasks within purely optical networks.

In another preferred drop-and-continue module having an optical filter according to the present invention, the optical filter is connected downstream of a branching device for optical signals. It is then possible to produce the drop-and-continue functionality by using purely optical hardware components.

The present invention is furthermore achieved by a cross-connect module which includes at least one optical filter according to the present invention. As such, it is possible to provide a cross-connect module in which the reconfiguration can take place non-destructively. The possibility of controlling the transmission response of the optical filter by deliberately changing the

temperature allows the filter action of the optical filter to be suspended by the appropriate temperature selection. At this moment, the filter does not in any way interfere with adjacent channels since no reflection takes place. Tuning of the filter then can be advantageously carried out. When the optical spectrum is being changed, adjacent optical spectra are crossed without causing any effect on the signals that likewise may be transported in this circuit over these optical spectra. It is hence possible to select a new channel without thereby influencing, or even interfering with, the channels or the signal flow which need to be crossed in doing so. After the desired new spectrum or channel has been reached, the reconfiguration is completed by resetting the temperature in such a way that the filter action restarts. This is preferably done by returning the difference in refractive indices to a magnitude greater than zero by the temperature change.

A preferred cross-connect module of the present invention includes at least one add-and-drop module. Accordingly, it is then possible to construct the cross-connect module from add-and-drop modules.

Another preferred cross-connect module of the present invention has at least one quad circulator and/or at least one Mach-Zehnder structure. It is possible to reduce the number of circulators used.

A cross-connect device is preferably provided which contains a number of series-connected cross-connect modules of the present invention. Through this arrangement, it is possible to cascade the circuit arrangements and hence interconnect even more lines.

In a preferred method of the present invention for the non-destructive tuning of a filter, the filter loses its filter characteristic as a result of a first temperature change, then the tuning of the filter is carried out, and then the filter regains its filter characteristic as a result of a second temperature change. This method permits non-destructive reconfiguration of purely optical network elements. The exploitation of the thermo-optical effect to influence the quality factor of the resonance of the filter makes it possible to adjust the filter, by a first

temperature change, in such a way that it loses its filter characteristic. This is preferably done by adjusting the temperature-dependent refractive indices in such a way that the difference becomes zero. So long as the filter has been "switched off" in this way, the tuning of the filter can be carried out without influencing adjacent channels or channels which are crossed. Once the new channel has been reached, i.e. the filter has been tuned to the new optical spectrum, the filter is "switched on" again by a second temperature change. In doing so, the temperature is preferably changed in such a way that the refractive indices again have a predetermined difference.

As such, a method for the non-destructive reconfiguration of purely optical network elements, in particular of the filter according to the present invention, is procured.

The optical filters of the present invention are particularly preferably used for the production of a circuit having add-and-drop functionality, and/or a circuit having drop-and-continue functionality, and/or a circuit having multicast functionality, and/or a circuit having dual-homing functionality, and/or a circuit having cross-connect functionality. Multicast is the deliberate linking of a plurality number of selected receivers to one transmitter (also referred to as group call). Dual homing is the connection of one receiver via two different network elements and paths. Pursuant to this arrangement, it is possible to provide purely optical network elements which have the functionalities referred to above and are at the same time non-destructively tunable or reconfigurable.

Additional features and advantages of the present invention are described in, and will be apparent from, the Detailed Description of the Preferred Embodiments and the Drawings.

DESCRIPTION OF THE DRAWINGS

Figure 1 shows a known add-drop-continue module;

Figure 2 shows an add-drop-continue module according to the present invention;

Figure 3 shows a variant of the add-drop-continue module of the present invention;

Figure 4 shows a possible filter construction;

Figure 5 shows the transmission diagram of the band-stop filter;

Figure 6 shows the transmission diagram of the band-stop filter in the case of a drop-and-continue function;

Figure 7 shows an add-drop-continue device having a series circuit in which a number of add-drop-continue modules are connected together;

Figure 8 shows a variant for the simultaneous extraction/injection of a number of WDM channels;

Figure 9 shows a standard optical cross-connect module (OXC) having optical n x n space-switching subunits;

Figure 10 shows a schematic representation of a cross-connect module in WDM-systems;

Figure 11 shows cascaded cross-connect modules;

Figure 12 shows a circuit according to the present invention of a cross-connect module; and

Figure 13 shows another circuit according to the present invention of a cross-connect module.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The add-drop-continue module represented in Figure 1 has already been explained in the introduction to the description. The splitter SP and the optical switch SW may be omitted if a tunable filter is being used which has resonant attenuation, so that a specific component of the energy of an optical signal, for example half of the energy, is reflected and the remaining component is forwarded via the second circulator.

Figure 2 represents such an add-drop-continue module. It contains a first circulator ZI1, a tunable filter BSF and a second circulator ZI2. The

transmission frequency of the filter can be continuously altered. The module ~~can~~ therefore can be used for a plurality number of wavelengths.

The attenuation of the filter can be changed by deliberately controlling the temperature, so that one signal range D_k is reflected by the filter and branched off, and the other signal component C_k is transmitted. It is hence possible to switch between the add-drop function and the drop-and-continue function using the same element, without optical switches being required. Of course, no signal is inserted in the drop-and-continue function (represented in Figure 2).

Figure 3 represents a variant of the add-drop-continue module, in which the second circulator has been replaced by a coupler KO. Although this variant is lees expensive, the coupler has greater attenuation.

If only the drop-and-continue function is to be produced, the second circulator or coupler may, of course, be omitted in a drop-and-continue module.

Figure 4 represents a possible embodiment of the filter in planar technology. The filter consists of an optically conductive material, generally quartz glass, and is essentially formed by a first region B1 having a temperature-dependent refractive index n_1 (t), (t - temperature), in which the essential energy component of the light is guided, and a second region B2 having a different temperature-dependent refractive index n_2 (t) regions. Only non-essential components of the light are guided in other regions, the substrate SUB and the superstrate SUP. As such, they are only non-essentially involved in the filter action. The interface between the two regions 1 and 2 presents a wave structure of period λ, which has been produced by suitable diffusion or mechanical processing (grating). In the known fashion, this geometrical structure has a wavelength-selective transmission and reflection response, which is represented in Figure 5.

The resonant wavelength λ_k is essentially determined by the period of the interface. The transmission attenuation is determined essentially by, besides the grating length and the grating amplitude, the difference in refractive index n_1 - n_2.

The resonant wavelength λ_K can be altered by mechanical pressure P (represented by dashes in Figure 5). If, for example, a wavelength multiplex signal λ_1, λ_2 ... λ_N (the same notation is used here for the optical signals as for the wavelengths) is fed into the filter, then one specific wavelength λ_K will be reflected whereas all the other wavelengths will be forwarded with very little attenuation.

A heating element HE can be used to heat the filter, so that the filter action is reduced and the transmission attenuation is decreased. A drop-and-continue function may be produced by setting an attenuation value of about 3 dB, as can be seen in Figure 6.

When the system is being reconfigured, the intention is for different optical signals, which have different wavelengths, to be branched off. By using the filter described above, this can be done without interfering with adjacent optical signals (or adjacent multiplex channels). The filter action is firstly removed by heating, so that all signals are forwarded. Tuning to the new wavelength is then carried out by exerting a mechanical pressure corresponding to this wavelength and subsequent cooling in order to restore the filter function, so that a different optical signal is now transmitted. Control circuits (not shown here) can be used to perform very accurate adjustment. Peltier elements may be used as heating and cooling elements.

Owing to their thermo-optical mechanism, these wavelength filters still have relatively high inertia. It is, however, already realistic to expect switchover times ~~of~~ from 10 ms to 500 ms, which is usually acceptable in the case of reconfigurations which are carried out infrequently.

In order for a number of optical signals λ_K, λ_{K+1} to be branched off and injected, a number of these modules Z1, BSF1, Z2, Z3, BSF2, Z4 are connected in series according to Figure 7.

Figure 8 shows an add-drop-continue module ZI1, BSF1, BSF2, BSF3, ZI2, in which a number of band-stop filters BSF1, BSF2, . . . BSFM are

interposed between two circulators. According to the number of filters, a number of optical signals λ_1 to λ_M are simultaneously injected or extracted. Individual signals can be branched off or injected by using a demultiplexer DMUX or a multiplexer MUX.

The band-stop filter also may be produced with a larger bandwidth. Instead of individual channels, it is then possible to extract and inject channel groups having adjacent channels.

Figure 9 shows a solution for a standard optical cross-connect (OXC) having optical n x n space-switching subunits. In this case, demultiplexers DMUX are connected via optical conductors to a space-switching subunit of dimension n x n, which are, in turn, connected to multiplexers MUX. An incoming optical multi-wavelength signal is decomposed by the demultiplexer DMUX into a single-wavelength signal. These single-wavelength signals are subsequently switched by using optical space-switching subunits of dimension n x n. The forward-switched single-wavelength signals from the various space-switching subunits then reach the multiplexer MUX, where they are recombined to form an output signal.

In the case of a circuit having, for example, 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors, 64 space-switching subunits of dimension 4 x 4 are needed.

Through this arrangement, it is possible to switch each single-wavelength signal of an incoming conductor to any desired output conductor.

Figure 10 gives a schematic representation of a cross-connect module having bundled cross-connect functionality in WDM systems. In this case, wavelengths 1 to n arrive on line 1. The wavelengths 1 to i and l to m on lines 1 and 2 are connected together, m describing the maximum number of parallel wavelength signals per fiber in the WDM system and i and l being dynamically variable numbers in the range $1 \leq i \leq l \leq m$. Similar considerations apply for lines 3 and 4. This connection is indicated by the solid stroke. The dashed lines

respectively represent the connection between line 1 and line 3, and between line 2 and line 4, for the wavelengths i to j and k to l, where i, j, k, l are dynamically variable numbers in the range $1 \leq i \leq j \leq j \leq k \leq l \leq m$.

The dotted lines represent the connections between lines 1 and 4, and between lines 3 and 2, in which the wavelength bundles j to k are switched together, where i, j, k, l are dynamically variable numbers in the range $1 \leq i \leq j \leq j \leq k \leq l \leq m$.

Using this circuit arrangement, it is possible to interconnect wavelength bundles in WDM systems with a cross-connect functionality.

Figure 11 gives a schematic representation of cascaded cross-connect modules. By connecting circuits of Figure 10 in succession, it is possible to produce more comprehensive cross-connect functionalities in WDM systems. Two such circuits have been cascaded in Figure 11, but it is also possible to cascade other circuits and use them in double-star topology, star topology or in meshed networks.

Figure 12 represents a circuit arrangement according to the present invention with bundled cross-connect functionality. Four conductors L1 to L4 are represented, which can be interconnected together. Circulators ZI1 to ZI12 are furthermore provided. These are triple circulators. Optical filters according to the present invention are furthermore provided as band-stop filters BS1 to BS6.

The way in which the circuit operates will be explained with reference to the division of the signals arriving on L2 according to the cross-connect functionality represented in Figure 10.

The incoming multi-wavelength signal on L2 is completely forwarded via the optical circulator ZI1, in the direction of the arrow, toward the next gate and encounters the optical band-stop filter BS1. This filter reflects the wavelength channels OCH i to l that are to be extracted, and the remaining channels are transmitted. In the same way, the wavelength channels i to l are extracted from the lines 1, 3 and 4.

The multi-wavelength signal (i to l) that is extracted on L2 is completely forwarded via the optical circulator ZI5, in the direction of the arrow, toward the next gate and encounters the optical band-stop filter BS3. This filter reflects the wavelength channels OCH j to k, and the remaining channels are transmitted. The multi-wavelength signal that is extracted from line 1 and forwarded to the circulator ZI6 is reflected from the same optical band-stop filter BS3. Conversely, the transmitted wavelength channels OCH i to j and OCH k to l are exchanged at the band-stop filter BS3. The same principle is used to process the wavelength bundles extracted from line 3 and line 4.

The multi-wavelength signal coming from the circulator ZI5 is fed via the circulator Z12 to the line L4. In a similar way, the multi-wavelength signals coming from the circulators ZI6, ZI7, ZI8 are fed to the appropriate line.

The band-stop filters BS1 to BS6 are of broadband design, so that they cover a number of wavelength channels. If one of the filter edges lies outside the wavelength spectrum, then this situation can be used to produce a high-pass or low-pass function. The selection of a wavelength bundle is made possible by the adjustment parameter f at the band-stop filter, which is labeled with the corresponding indices. The "neutralization" of the filter preferably may be performed during reconfigurations by means of the transmission attenuation d.

By using the optical filter according to the present invention in this circuit arrangement, it is possible to extract variable complete wavelength bundles from a multi-wavelength signal.

Figure 13 represents a similar circuit arrangement to Figure 12, but in which the triple circulators have been replaced by quad circulators. As such, it is possible to replace the 12 circulators which were used in the circuit arrangement according to Figure 12 by 8 quad circulators. The circulators may also may be replaced by Mach-Zehnder structures.

Accordingly, simple allocation of selected multi-wavelength bundles to different multi-wavelength channels is possible. The complexity of the system

is reduced, in comparison with cross-connect modules of the prior art according to Figure 9, to a commensurately greater extent when the number of parallel wavelengths that are to be extracted per conductor is high. In the case of a circuit arrangement having, for example, 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors, the solution variant having space-switching subunits and demultiplexers/multiplexers requires 64 space-switching subunits of dimension 4 x 4, whereas only 6 band-stop filters need to be used in the circuit arrangements proposed in Figures 12 and 13.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

An optical filter, adjustable add-drop-continue module and circuit for bundled cross-connect functionality, wherein the transmission response of the optical filter is varied by changing its temperature, tuning of the filter can be carried out by mechanical pressure or tension, the filter can be used to produce add-drop-continue modules which are suitable both for add-drop operation and for drop-continue operation, and cross-connect modules can be constructed from the optical filters.

In the claims:

On page 17, cancel line 1, and substitute the following left-hand justified heading therefor:

We Claim as Our Invention:

Please cancel claims 1-19, without prejudice, and substitute the following claims therefor:

20. An optical filter for producing a drop-and-continue function, comprising:

a wavelength-selective grating having temperature-dependent reflection and transmission characteristics; and

a device for adjusting a temperature of the grating, wherein a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted.

21. An optical filter for producing a drop-and-continue function as claimed in claim 20, wherein filter action of the optical filter is lost upon a further temperature change.

22. An optical filter for producing a drop-and-continue function as claimed in claim 20, wherein the grating includes at least two regions in an optically transparent material, each of the at least two regions having respectively

different temperature-dependent refractive indices such that a difference between the refractive indices is at least approximately zero at one temperature within a temperature-controllable working range.

23. An optical filter for producing a drop-and-continue function as claimed in claim 22, wherein the filter is designed in planar technology.

24. An optical filter for producing a drop-and-continue function as claimed in claim 20, wherein the filter is designed as a tunable band-stop filter.

25. An optical filter for producing a drop-and-continue function as claimed in claim 24, wherein a bandwidth of the filter is tuned to a bandwidth of a transmission channel.

26. An optical filter for producing a drop-and-continue function as claimed in claim 24, wherein a bandwidth of the filter is tuned to a bandwidth of a plurality of adjacent transmission channels.

27. An optical filter for producing a drop-and-continue function as claimed in claim 24, wherein tuning is carried out by at least one of mechanical pressure, tension and bending.

28. An add-drop-continue module, comprising:

an insertion device;

a branching device for optical signals; and

an optical filter for producing a drop-and-continue function, the optical filter including a wavelength-selective grating having temperature-dependent reflection and transmission characteristics, and a device for adjusting a temperature of the grating such that a first signal component to be branched off is

reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted, wherein the optical filter is connected between the branching device and the insertion device.

29. An add-drop-continue module as claimed in claim 28, further comprising:

a plurality of optical filters connected between the branching device and the insertion device.

30. An add-drop-continue module as claimed in claim 28, wherein at least one of the branching device and the insertion device is a circulator.

31. An add-drop-continue device formed of a plurality of add-drop-continue modules connected in series, each of the add-drop-continue modules comprising:

an insertion device;

a branching device for optical signals; and

an optical filter for producing a drop-and-continue function, the optical filter including a wavelength-selective grating having temperature-dependent reflection and transmission characteristics, and a device for adjusting a temperature of the grating such that a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted, wherein the optical filter is connected between the branching device and the insertion device.

32. A drop-and-continue module, comprising:

a branching device for optical signals; and

a tunable band-stop optical filter for producing a drop-and-continue function, the filter including a wavelength-selective grating having temperature-

dependent reflection and transmission characteristics, and a device for adjusting a temperature of the grating such that a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted, wherein the optical filter is connected downstream of the branching device.

33. A cross-connect module, comprising:

a plurality of inputs;

a plurality of outputs; and

at least one optical filter for producing a drop-and-continue function, the filter including a wavelength-selective grating having temperature-dependent reflection and transmission characteristics, and a device for adjusting a temperature of the grating such that a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted.

34. A cross-connect module, comprising:

a plurality of inputs;

a plurality of outputs; and

at least one add-drop-continue module having an optical filter connected between a branching device for optical signals and an insertion device, wherein the optical filter produces a drop-and-continue function and includes a wavelength-selective grating having temperature-dependent reflection and transmission characteristics, and a device for adjusting a temperature of the grating such that a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted.

35. A cross-connect module as claimed in claim 33, wherein at least one of the branching device and the insertion device is a quad circulator.

36. A cross-connect device including a plurality of series-connected cross-connect modules, each of the cross-connect modules comprising:

a plurality of inputs;

a plurality of outputs; and

at least one optical filter for producing a drop-and-continue function, the filter including a wavelength-selective grating having temperature-dependent reflection and transmission characteristics, and a device for adjusting a temperature of the grating such that a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted.

37. A method for tuning an optical filter without interfering with transmitted signals, wherein the optical filter produces a drop-and-continue function and includes a wavelength-selective grating having temperature-dependent reflection and transmission characteristics and a device for adjusting a temperature of the grating such that a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted, the method comprising the steps of:

adjusting the optical filter such that, as a result of a first temperature change, the optical filter loses its filter characteristic;

tuning the optical filter to a predetermined new wavelength; and

subsequently adjusting the optical filter, as a result of a further temperature change, such that the optical filter regains its filter characteristic at a newly adjusted wavelength.

38. A method of using an optical filter to assist in the production of a circuit having at least one of add-and-drop functionality, drop-and-continue functionality, multicast functionality, dual-homing functionality and cross-connect functionality, the method comprising the steps of:

providing an optical filter for producing a drop-and-continue function;

providing a wavelength-selective grating within the optical filter having temperature-dependent reflection and transmission characteristics; and

providing a device in the optical filter for adjusting a temperature of the grating, wherein a first signal component to be branched off is reflected by the grating and a second signal component having a same wavelength as the first signal component is transmitted.

REMARKS

The present amendment makes editorial changes and corrects typographical errors in the specification, which includes the Abstract, in order to conform the specification to the requirements of United States Patent Practice. No new matter is added thereby. Attached hereto is a marked-up version of the changes made to the specification by the present amendment. The attached page is captioned "**Version With Markings To Show Changes Made**".

In addition, the present amendment cancels original claims 1-19 in favor of new claims 20-38. Claims 20-38 have been presented solely because the revisions by red-lining and underlining which would have been necessary in claims 1-19 in order to present those claims in accordance with preferred United States Patent Practice would have been too extensive, and thus would have been too burdensome. The present amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 USC §§103, 102, 103 or 112. Indeed, the cancellation of claims 1-19 does not constitute an intent on the part of the Applicants to surrender any of the subject matter of claims 1-19.

Early consideration on the merits is respectfully requested.

Respectfully submitted,

(Reg. No. 39,056)

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VERSIONS WITH MARKINGS TO SHOW CHANGES MADE

In The Specification:

The Specification of the present application, including the Abstract, has been amended as follows:

SPECIFICATION

TITLE

OPTICAL FILTER, ADJUSTABLE ADD-DROP-CONTINUE MODULE AND CIRCUIT FOR BUNDLED CROSS-CONNECT FUNCTIONALITY

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a tunable optical filter, ~~and~~ to an ~~add-drop~~ add-drop-continue module ~~according to the preamble of claim 7~~ which is produced using this filter, to an ~~add-drop~~ add-drop-continue device and to a circuit ~~arrangement~~ for bundled cross-connect functionality.

Description of the Prior Art

In order to ensure minimal interference during signal transmission, optical wavelength multiplex networks (WDM networks) are redundantly designed. Ring structures are often provided. At ~~a~~ junctions between different rings, "drop-and-continue" functions are implemented~~,~~; i.e., the signal is split and is both forwarded through the original ring and transferred into the new ring. For purely optical production of a drop-and-continue function, it is possible to use wavelength demultiplexers, optical switches and wavelength multiplexers.

For the production of add-drop functions, modules from the company High Wave Technologies are known~~,~~ which consist of two circulators with interposed tunable filters. In the event of tuning due to a configurational change, however, the retuning of one WDM channel generally interferes with the signals of other WDM channels. These modules are not intended for drop-and-continue functions. It is, however, conceivable to supplement this module with splitters and switches~~,~~ in order to produce the drop-and-continue function.

Figure 1 represents such an "add-drop-continue module". It consists of a splitter SP~~,~~ which divides the optical signal into two signals of roughly equal strength. One component is fed via two circulators having a tunable filter connected in between. In order to produce the drop-and-continue function, one signal component D_k is branched off via the first circulator and the other signal component C_k is forwarded via an optical switch SW (the switch position which is represented).

In the case of an add-drop function, one signal component D_k is likewise branched off, but a new signal A_k having the same wavelength is simultaneously inserted via the second circulator ZI2. Owing to the use of the optical splitter, the module has in principle an attenuation of at least 3 dB. Depending on the number of add-drop functions, the aforementioned add-drop element is multiply connected in series, so that the attenuation is further increased significantly.

The cross-connect functionality in optical multi-wavelength multiplex systems (WDM) is needed so that a specific wavelength signal of an incoming multi-wavelength signal can be distributed in any desired direction.

"WDM Gridconnect - ein transparentes faseroptisches Kommunikationsnetz mit Faser- und Wellenlängenmultiplex" [WDM grid-connect - a transparent fiber-optic communications network having fiber and wavelength multiplex] by Hubert Anton Jäger, published by Hartung-Gorre-Verlag, Constance [Germany] 1998 describes a standard optical cross-connect (OXC). Such an optical cross-connect (OXC) having optical n x n space-switching subunits with n incoming bidirectional multi-wavelength signals, each having k wavelengths, is represented in Figure 9. In this case, the optical multi-wavelength signal is decomposed ~~by means of~~ via optical wavelength demultiplexers DMUX into k single-frequency signals which are subsequently switched to any desired output of the space-switching subunit by using optical space-switching subunits of dimension n x n. The single-frequency signals

coming together from the outputs of the space-switching subunits are coupled and forwarded ~~by means of~~ via a multiplexer MUX.

A disadvantage with this is the large outlay on equipment which is incurred when making these optical cross-connects (OXC). A circuit ~~arrangement~~ having, for example, 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors needs 64 space-switching subunits of dimension 4 x 4. Furthermore, 64 fiber-optic connections to the corresponding space-switching subunits of dimension n x n have to be installed per multiplexer MUX and demultiplexer DMUX, respectively, plus the same number again from the space-switching subunits to the demultiplexers DMUX or multiplexers MUX on the other side.

JP 1 023 479/US 5 963 685 describes an add-drop module which contains a ~~plurality~~ number of reflection filters whose frequencies can be adjusted by mechanical pressure and changing the temperature.

The patent US 5,707,375 likewise specifies an add-drop device whose filters have different and mutually asymmetric edges. By tuning the filters in terms of wavelength, it is possible to obtain complete transmission, complete reflection or partial transmission and reflection. In this solution, it is necessary to have double the number of filters and adjustment devices. However, readjustment of the wavelength during operation leads to interference with the other signals.

The European patent application EP 0854 378 A2 describes a thermal-optical component which has a splitter and a tunable grating filter. The arrangement operates as an optical switch and can be used to produce add-drop functions. The patent US 5,408,319 describes an optical demultiplexer in which tuning to a specific wavelength is carried out not mechanically but by changing the temperature.

The patent application WO 98/04854 describes an add-drop module which can be tuned by heating strips or magnetoresistors.

WO 99/42893 also discloses a tunable add-drop multiplexer. In order to tune the wavelength, the refractive index of the filter material is changed, for example by heating.

The known principles are unsuitable or too elaborate for producing an add-drop-continue function.

It is an object of the present invention to propose an add-drop-continue module having little attenuation, as well as a filter which is suitable for its production and which has a variable transmission characteristic. This module is also intended to permit reconfiguration of channels without causing interference.

It is another object of the present invention to propose a circuit ~~arrangement~~ having cross-connect functionality~~,~~ which allows simple allocation of dynamically assembled multi-wavelength bundles to different conductors. It is another object of the present invention to propose a circuit ~~arrangement~~ having cross-connect functionality, which permits reduced complexity of the system. In this case as well, reconfiguration of channels is intended to be made possible without causing interference.

~~The object is achieved by a filter specified in claim 1, an add-drop-continue module specified in claim 6 and a "cross-connect module" for producing bundled cross-connect functionality as claimed in the dependent claims. Variants of this module are furthermore specified.~~

~~Advantageous refinements are specified in the dependent claims.~~

SUMMARY OF THE INVENTION

~~The~~ Accordingly, there is a special advantage of the module of the present invention, and of the circuit ~~arrangement~~ for producing bundled cross-connect functionality, ~~is~~ due to ~~the~~ a filter whose frequency and attenuation can be varied. This not only makes it possible to select different channels~~;~~ , it also results in no optical switches ~~are~~ being necessary for producing add-drop, drop-continue or cross-connect functions. Reconfiguration of the network can be carried out without interference to adjacent signals.

In particular, the present invention is achieved by an optical filter, wherein a device ~~(HE)~~ is provided for adjusting the transmission response ~~by means of~~ via a deliberate temperature change. The effect achieved by adjusting the transmission response through temperature changes is that the optical filter is non-destructively reconfigurable, which has never before been possible in the case of purely optical network elements except with expensive optical circuit technology (wavelength multiplexers, wavelength demultiplexers, space-switching matrices). In contrast to standard wavelength filters, the transmission attenuation can also be adjusted in addition to the resonant wavelength in the optical filter according to the present invention.

In another preferred exemplary embodiment of the optical filter, at least two regions ~~(B1, B2)~~ in an optically transparent material, which have different temperature-dependent refractive indices $\cancel{n_1 (t) \text{ and } n_2 (t)}$, are essentially involved in the optical waveguiding and/or the filter action, and wherein the difference between the refractive indices $\cancel{n_1 (t) \text{ and } n_2 (t)}$ is at least approximately zero at one temperature within the temperature-controllable working range. The temperature-dependent difference in refractive index between two optical materials is hence influenced by the deliberate change of temperature. This exploitation of the thermo-optical effect to influence the quality factor of the resonance is performed by adjusting the resonant wavelength $\cancel{\lambda_k}$ and the transmission attenuation d for this wavelength. On the grounds of conservation of energy, the reflection factor is obtained directly from the transmission response in the ideal case. Energy components which are not transmitted must necessarily be reflected. The resonant wavelength $\cancel{\lambda_k}$ is essentially influenced by the period $\cancel{\Lambda}$ of the interfaces. The transmission attenuation is ~~given~~ essentially given by (besides the grating length $\cancel{Z}$ and the grating amplitude) the difference in refractive ~~index~~ $\cancel{n_1 - n_2}$ indices.

The optical filter according to the present invention is advantageously designed in planar technology. This facilitates integration into existing circuitry.

The optical filter is furthermore preferably produced as a fiber grating. The difference in refractive index between two optical layers involved in the waveguiding is of essential importance in the case of fiber gratings as well. The principle employed here, namely to influence the transmission attenuation by a thermal refractive-index change, ~~may therefore~~ preferably may be used in the case of such filters as well.

An optical filter is ~~particularly~~ preferably designed as a tunable band-stop filter. This facilitates the extraction of a frequency band. The latter is advantageous especially in purely optical telecommunications networks.

The tuning of the band-stop filter is ~~particularly~~ preferably carried out by mechanical pressure, tension or bending. ~~By means of this~~ As such, the wavelength to be filtered in the optical spectrum can be selected by exposing the band-stop filter to mechanical influence.

The present invention is furthermore achieved by an add-drop-continue module having an optical filter according to the present invention, wherein the tunable optical filter ~~(BSF)~~ is arranged between a branching device ~~(ZI1)~~ for optical signals and an insertion device ~~(ZI2, KO)~~. ~~By means of this~~ Accordingly, an add-drop-continue module can be constructed using an optical filter according to the present invention. The signal is split in the branching device for optical signals, and one component is fed to the gate of the optical filter according to the present invention. The component to be extracted is reflected and forwarded, whereas the component to be injected is inserted by the insertion device ~~(ZI2, KO)~~.

In another preferred add-drop-continue module of the present invention, a ~~plurality~~ number of optical filters ~~(BSF1 to BSFM)~~ are arranged between a branching device ~~(ZI1)~~ for optical signals and an insertion device ~~(ZI2, KO)~~. ~~By means of this~~ Though this arrangement, it is possible for a ~~plurality~~ number of individually adjustable optical spectra to be extracted from the signal

and, ~~particularly~~ preferably, to ~~the~~ be injected or re-extracted via multiplexers and demultiplexers, respectively.

In another preferred add-drop-continue module of the present invention, circulators are provided as the branching devices ~~(ZI1)~~ and as the insertion device ~~(ZI2)~~. ~~By means of this~~ As such, the injection and extraction of the signals can be carried out using known hardware components. Triple circulators are preferably used for this~~. Quad~~ and quad circulators are ~~particularly~~ even more preferably used. It is also possible to use Mach-Zehnder structures.

The objects of the present invention ~~is particularly~~ are preferably achieved by an add-drop-continue device, wherein a ~~plurality~~ number of series-connected add-drop modules of the present invention are provided. ~~By means of this~~ Accordingly, it is possible to fulfill a very wide variety of circuit tasks within purely optical networks.

In another preferred drop-and-continue module having an optical filter according to the present invention, the optical filter is connected downstream of a branching device for optical signals. ~~By means of this it~~ It is then possible to produce the drop-and-continue functionality by using purely optical hardware components.

The present invention is furthermore achieved by a cross-connect module which ~~comprises~~ includes at least one optical filter according to the present invention. ~~By means of this~~ As such, it is possible to provide a cross-connect module in which the reconfiguration can take place non-destructively. The possibility of controlling the transmission response of the optical filter by deliberately changing the temperature allows the filter action of the optical filter to be suspended by the appropriate temperature selection. At this moment, the filter does not in any way interfere with adjacent channels since no reflection takes place. Tuning of the filter then can be ~~now~~ advantageously ~~be~~ carried out. When the optical spectrum is being changed, adjacent optical spectra are crossed without causing any effect on the signals that ~~may~~ likewise maybe transported in

this circuit over these optical spectra. It is hence possible to select a new channel without thereby influencing, or even interfering with, the channels or the signal flow which need to be crossed in doing so. After the desired new spectrum or channel has been reached, the reconfiguration is completed by resetting the temperature in such a way that the filter action restarts. This is preferably done by returning the difference in refractive ~~index ($n_1 - n_2$)~~ indices to a magnitude greater than zero by the temperature change.

A preferred cross-connect module of the present invention ~~comprises~~ includes at least one add-and-drop module. ~~By means of this~~ Accordingly, it is then possible to construct the cross-connect module from add-and-drop modules.

Another preferred cross-connect module of the present invention has at least one quad circulator and/or at least one Mach-Zehnder structure. ~~By means of this, it~~, It is possible to reduce the number of circulators used.

A cross-connect device is preferably provided which contains a ~~plurality~~ number of series-connected cross-connect modules of the present invention. ~~By means of this~~ Through this arrangement, it is possible to cascade the circuit arrangements and hence interconnect even more lines.

In a preferred method of the present invention for the non-destructive tuning of a filter, the filter loses its filter characteristic as a result of a first temperature change, then the tuning of the filter is carried out, and then the filter regains its filter characteristic as a result of a second temperature change. This method permits non-destructive reconfiguration of purely optical network elements. The exploitation of the thermo-optical effect to influence the quality factor of the resonance of the filter makes it possible to adjust the filter, by a first temperature change, in such a way that it loses its filter characteristic. This is preferably done by adjusting the temperature-dependent refractive indices in such a way that the difference becomes zero. So long as the filter has been "switched off" in this way, the tuning of the filter can be carried out without influencing adjacent channels or channels which are crossed. Once the new channel has been

reached, i.e. the filter has been tuned to the new optical spectrum, the filter is "switched on" again by a second temperature change. In doing so, the temperature is preferably changed in such a way that the refractive indices again have a predetermined difference.

~~By means of this~~ As such, a method for the non-destructive reconfiguration of purely optical network elements, in particular of the filter according to the present invention, is procured.

The optical filters of the present invention are particularly preferably used for the production of a circuit having add-and-drop functionality~~;~~, and/or a circuit having drop-and-continue functionality~~;~~, and/or a circuit having multicast functionality~~;~~, and/or a circuit having dual-homing functionality~~;~~, and/or a circuit having cross-connect functionality. Multicast is the deliberate linking of a plurality number of selected receivers to one transmitter (also referred to as group call). Dual homing is the connection of one receiver via two different network elements and paths. ~~By means of this~~ Pursuant to this arrangement, it is possible to provide purely optical network elements which have the functionalities referred to above and are at the same time non-destructively tunable or reconfigurable.

~~The invention and other advantageous features will be described in more detail with reference to exemplary embodiments.~~

Additional features and advantages of the present invention are described in, and will be apparent from, the Detailed Description of the Preferred Embodiments and the Drawings.

DESCRIPTION OF THE DRAWINGS

Figure 1 shows ~~an~~ a known add-drop-continue module~~,~~;

Figure 2 shows an add-drop-continue module according to the present invention~~,~~;

Figure 3 shows a variant of ~~this~~ the add-drop-continue module of the present invention~~,~~;

Figure 4 shows a possible filter construction~~,~~;

Figure 5 shows the transmission diagram of the band-stop filter~~,~~;

Figure 6 shows the transmission diagram of the band-stop filter in the case of a drop-and-continue function~~,~~;

Figure 7 shows an add-drop-continue device having a series circuit in which a ~~plurality~~ number of add-drop-continue modules are connected together~~,~~ ;

Figure 8 shows a variant for the simultaneous extraction/injection of a ~~plurality~~ of WDM channels;

Figure 9 shows a standard optical cross-connect module (OXC) having optical n x n space-switching subunits~~,~~;

Figure 10 shows a schematic representation of a cross-connect module in WDM-systems~~,~~;

Figure 11 shows cascaded cross-connect modules~~,~~;

Figure 12 shows a circuit ~~arrangement~~ according to the present invention of a cross-connect module~~,~~ ; and

Figure 13 shows another circuit ~~arrangement~~ according to the present invention of a cross-connect module.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The add-drop-continue module represented in Figure 1 has already been explained in the introduction to the description. The splitter SP and the optical switch SW may be omitted if a tunable filter is being used which has resonant attenuation, so that a specific component of the energy of an optical signal, for example half ~~said~~ of the energy, is reflected and the remaining component is forwarded via the second circulator.

Figure 2 represents such an add-drop-continue module. It contains a first circulator ZI1, a tunable filter BSF and a second circulator ZI2. The transmission frequency of the filter can be continuously altered. The module ~~can~~ therefore can be used for a plurality number of wavelengths.

The attenuation of the filter can be changed by deliberately controlling the temperature, so that one signal range D_k is reflected by the filter and branched off, and the other signal component C_k is transmitted. It is hence possible to switch between the add-drop function and the drop-and-continue function using the same element, without optical switches being required. Of course, no signal is inserted in the drop-and-continue function (represented in Figure 2).

Figure 3 represents a variant of the add-drop-continue module, in which the second circulator has been replaced by a coupler KO. Although this variant is lees expensive, the coupler has greater attenuation.

If only the drop-and-continue function is to be produced, the second circulator or coupler may, of course, be omitted in a drop-and-continue module.

Figure 4 represents a possible embodiment of the filter in planar technology. The filter consists of an optically conductive material, generally quartz glass, and is essentially formed by a first region B1 having a temperature-dependent refractive index n_1 (t), (t - temperature), in which the essential energy component of the light is guided, and a second region B2 having a different temperature-dependent refractive index n_2 (t) regions. Only non-essential components of the light are guided in other regions, the substrate SUB and the superstrate SUP. ~~They are hence~~ As such, they are only non-essentially involved in the filter action. The interface between the two regions 1 and 2 presents a wave structure of period λ, which has been produced by suitable diffusion or mechanical processing (grating). In the known fashion, this geometrical structure has a wavelength-selective transmission and reflection response, which is represented in Figure 5.

The resonant wavelength λ_k is essentially determined by the period of the interface~~; the~~ . The transmission attenuation is determined essentially by, besides the grating length and the grating amplitude, the difference in refractive index $n_1 - n_2$.

The resonant wavelength λ_K can be altered by mechanical pressure P (represented by dashes in Figure 5). If, for example, a wavelength multiplex signal

$\lambda_1, \lambda_2 \ldots \lambda_N$ (the same notation is used here for the optical signals as for the wavelengths) is fed into the filter, then one specific wavelength λ_K will be reflected whereas all the other wavelengths will be forwarded with very little attenuation.

A heating element HE can be used to heat the filter, so that the filter action is reduced and the transmission attenuation is decreased. A drop-and-continue function may be produced by setting an attenuation value of about 3 dB, as can be seen in Figure 6.

When the system is being reconfigured, the intention is for different optical signals, which have different wavelengths, to be branched off. By using the filter described above, this can be done without interfering with adjacent optical signals (or adjacent multiplex channels). The filter action is firstly removed by heating, so that all signals are forwarded. Tuning to the new wavelength is then carried out by exerting a mechanical pressure corresponding to this wavelength and subsequent cooling in order to restore the filter function, so that a different optical signal is now transmitted. Control circuits (not shown here) can be used to perform very accurate adjustment. Peltier elements may be used as heating and cooling elements.

Owing to their thermo-optical mechanism, these wavelength filters still have relatively high inertia. It is, however, already realistic to expect switchover times ~~of~~ from 10 ms to 500 ms, which is usually acceptable in the case of reconfigurations which are carried out infrequently.

In order for a ~~plurality~~ number of optical signals λ_K, λ_{K+1} to be branched off and injected, a ~~plurality~~ number of these modules Z1, BSF1, Z2, Z3, BSF2, Z4 are connected in series according to Figure 7.

Figure 8 shows an add-drop-continue module ZI1, BSF1, BSF2, BSF3, ZI2, in which a ~~plurality~~ number of band-stop filters BSF1, BSF2, . . . BSFM are interposed between two circulators. According to the number of filters, a plurality number of optical signals λ_1 to λ_M are simultaneously injected or extracted. Individual signals can be branched off or injected by using a demultiplexer DMUX or a multiplexer MUX.

~~It should also be mentioned that the~~ The band-stop filter ~~may~~ also may be produced with a larger bandwidth. Instead of individual channels, it is then possible to extract and inject channel groups ~~comprising~~ having adjacent channels.

Figure 9 shows a solution for a standard optical cross-connect (OXC) having optical n x n space-switching subunits. In this case, demultiplexers DMUX are connected via optical conductors to a space-switching subunit of dimension n x n, which are, in turn, connected to multiplexers MUX. An incoming optical multi-wavelength signal is decomposed by the demultiplexer DMUX into a single-wavelength signal. These single-wavelength signals are subsequently switched by using optical space-switching subunits of dimension n x n. The forward-switched single-wavelength signals from the various space-switching subunits then reach the multiplexer MUX, where they are recombined to form an output signal.

In the case of a circuit ~~arrangement~~ having, for example, ~~e.g.~~ 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors, 64 space-switching subunits of dimension 4 x 4 are needed.

~~By means of~~ Through this arrangement, it is possible to switch each single-wavelength signal of an incoming conductor to any desired output conductor.

Figure 10 gives a schematic representation of a cross-connect module having bundled cross-connect functionality in WDM systems. In this case, wavelengths 1 to n arrive on line 1. The wavelengths 1 to i and 1 to m on lines 1

and 2 are connected together, m describing the maximum number of parallel wavelength signals per fiber in the WDM system and i and l being dynamically variable numbers in the range $1 \leq i \leq l \leq m$. Similar considerations apply for lines 3 and 4. This connection is indicated by the solid stroke. The dashed lines respectively represent the connection between line 1 and line 3, and between line 2 and line 4, for the wavelengths i to j and k to l, where i, j, k, l are dynamically variable numbers in the range $1 \leq i \leq j \leq j \leq k \leq l \leq m$.

The dotted lines represent the connections between lines 1 and 4, and between lines 3 and 2, in which the wavelength bundles j to k are switched together, where i, j, k, l are dynamically variable numbers in the range $1 \leq i \leq j \leq j \leq k \leq l \leq m$.

Using this circuit arrangement, it is possible to interconnect wavelength bundles in WDM systems with a cross-connect functionality.

Figure 11 gives a schematic representation of cascaded cross-connect modules. By connecting circuits of Figure 10 in succession, it is possible to produce more comprehensive cross-connect functionalities in WDM systems. Two such circuits have been cascaded in Figure 11, but it is also possible to cascade other circuits and use them in double-star topology, star topology or in meshed networks.

Figure 12 represents a circuit arrangement according to the <u>present</u> invention with bundled cross-connect functionality. Four conductors L1 to L4 are represented, which can be interconnected together. Circulators ZI1 to ZI12 are furthermore provided. These are triple circulators. Optical filters according to the <u>present</u> invention are furthermore provided as band-stop filters BS1 to BS6.

The way in which the circuit operates will be explained with reference to the division of the signals arriving on L2 according to the cross-connect functionality represented in Figure 10.

The incoming multi-wavelength signal on L2 is completely forwarded via the optical circulator ZI1, in the direction of the arrow, toward the next gate

and encounters the optical band-stop filter BS1. This filter reflects the wavelength channels OCH i to l that are to be extracted, and the remaining channels are transmitted. In the same way, the wavelength channels i to l are extracted from the lines 1, 3 and 4.

The multi-wavelength signal (i to l) that is extracted on L2 is completely forwarded via the optical circulator ZI5, in the direction of the arrow, toward the next gate and encounters the optical band-stop filter BS3. This filter reflects the wavelength channels OCH j to k, and the remaining channels are transmitted. The multi-wavelength signal that is extracted from line 1 and forwarded to the circulator ZI6 is reflected from the same optical band-stop filter BS3. Conversely, the transmitted wavelength channels OCH i to j and OCH k to l are exchanged at the band-stop filter BS3. The same principle is used to process the wavelength bundles extracted from line 3 and line 4.

The multi-wavelength signal coming from the circulator ZI5 is fed via the circulator Z12 to the line L4. In a similar way, the multi-wavelength signals coming from the circulators ZI6, ZI7, ZI8 are fed to the appropriate line.

The band-stop filters BS1 to BS6 are of broadband design, so that they cover a ~~plurality~~ number of wavelength channels. If one of the filter edges lies outside the wavelength spectrum, then this situation can be used to produce a high-pass or low-pass function. The selection of a wavelength bundle is made possible by the adjustment parameter f at the band-stop filter, which is labeled with the corresponding indices. The "neutralization" of the filter ~~may~~ preferably may be performed during reconfigurations by means of the transmission attenuation d.

By using the optical filter according to the present invention in this circuit arrangement, it is possible to extract variable complete wavelength bundles from a multi-wavelength signal.

Figure 13 represents a similar circuit arrangement to Figure 12, but in which the triple circulators have been replaced by quad circulators. ~~By means of~~

~~this~~ As such, it is possible to replace the 12 circulators which were used in the circuit arrangement according to Figure 12 by 8 quad circulators. The circulators may also may be replaced by Mach-Zehnder structures.

~~By means of this~~ Accordingly, simple allocation of selected multi-wavelength bundles to different multi-wavelength channels is possible. The complexity of the system is reduced, in comparison with cross-connect modules of the prior art according to Figure 9, to a commensurately greater extent when the number of parallel wavelengths that are to be extracted per conductor is high. In the case of a circuit arrangement having, for example, ~~e.g.~~ 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors, the solution variant having space-switching subunits and ~~de-~~demultiplexers/multiplexers requires 64 space-switching subunits of dimension 4 x 4, whereas only 6 band-stop filters need to be used in the circuit arrangements proposed in Figures 12 and 13.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

An optical filter, adjustable add-drop-continue module and circuit for bundled cross-connect functionality, wherein the transmission response of the optical filter is varied by changing its temperature, tuning of the filter can be carried out by mechanical pressure or tension, the filter can be used to produce add-drop-continue modules which are suitable both for add-drop operation and for drop-continue operation, and cross-connect modules can be constructed from the optical filters.

Description

Optical filter, adjustable add-drop-continue module and circuit arrangement for bundled cross-connect functionality

The invention relates to a tunable optical filter and to an add-drop module according to the preamble of claim 7 which is produced using this filter, to an add-drop device and to a circuit arrangement for bundled cross-connect functionality.

In order to ensure minimal interference during signal transmission, optical wavelength multiplex networks (WDM networks) are redundantly designed. Ring structures are often provided. At a junctions between different rings, "drop-and-continue" functions are implemented, i.e. the signal is split and is both forwarded through the original ring and transferred into the new ring. For purely optical production of a drop-and-continue function, it is possible to use wavelength demultiplexers, optical switches and wavelength multiplexers.

For the production of add-drop functions, modules from the company High Wave Technologies are known, which consist of two circulators with interposed tunable filters. In the event of tuning due to a configurational change, however, the retuning of one WDM channel generally interferes with the signals of other WDM channels. These modules are not intended for drop-and-continue functions. It is, however, conceivable to supplement this module with splitters and switches, in order to produce the drop-and-continue function.

Figure 1 represents such an "add-drop-continue module". It consists of a splitter SP, which

divides the optical signal into two signals of roughly equal strength. One component is fed via two circulators having a tunable filter connected in between. In order to produce the drop-and-continue function, one signal component D_k is branched off via the first circulator and the other signal component C_k is forwarded via an optical switch SW (the switch position which is represented).

In the case of an add-drop function, one signal component D_k is likewise branched off, but a new signal A_k having the same wavelength is simultaneously inserted via the second circulator ZI2. Owing to the use of the optical splitter, the module has in principle an attenuation of at least 3 dB. Depending on the number of add-drop functions, the aforementioned add-drop element is multiply connected in series, so that the attenuation is further increased significantly.

The cross-connect functionality in optical multi-wavelength multiplex systems (WDM) is needed so that a specific wavelength signal of an incoming multi-wavelength signal can be distributed in any desired direction.

"WDM Gridconnect - ein transparentes faseroptisches Kommunikationsnetz mit Faser- und Wellenlängenmultiplex" [WDM grid-connect - a transparent fiber-optic communications network having fiber and wavelength multiplex] by Hubert Anton Jäger, published by Hartung-Gorre-Verlag, Constance [Germany] 1998 describes a standard optical cross-connect (OXC). Such an optical cross-connect (OXC) having optical n x n space-switching subunits with n incoming bidirectional multi-wavelength signals, each having k wavelengths, is represented in Figure 9. In this case, the optical multi-wavelength signal is decomposed by means of optical wavelength demultiplexers DMUX into k single-frequency signals which are subsequently switched to any desired output of the space-switching subunit by using optical space-switching subunits of dimension n x n. The single-frequency signals coming together

from the outputs of the space-switching subunits are coupled and forwarded by means of a multiplexer MUX.

A disadvantage with this is the large outlay on equipment which is incurred when making these optical cross-connects (OXC). A circuit arrangement having, for example, 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors needs 64 space-switching subunits of dimension 4 x 4. Furthermore, 64 fiber-optic connections to the corresponding space-switching subunits of dimension n x n have to be installed per multiplexer MUX and demultiplexer DMUX, respectively, plus the same number again from the space-switching subunits to the demultiplexers DMUX or multiplexers MUX on the other side.

JP 1 023 479/US 5 963 685 describes an add-drop module which contains a plurality of reflection filters whose frequencies can be adjusted by mechanical pressure and changing the temperature.

The patent US 5,707,375 likewise specifies an add-drop device whose filters have different and mutually asymmetric edges. By tuning the filters in terms of wavelength, it is possible to obtain complete transmission, complete reflection or partial transmission and reflection. In this solution, it is necessary to have double the number of filters and adjustment devices. However, readjustment of the wavelength during operation leads to interference with the other signals.

The European patent application EP 0854 378 A2 describes a thermal-optical component which has a splitter and a tunable grating filter. The arrangement operates as an optical switch and can be used to produce add-drop functions.

The patent US 5,408,319 describes an optical demultiplexer in which tuning to a specific wavelength is carried out not mechanically but by changing the temperature.

The patent application WO 98/04854 describes an add-drop module which can be tuned by heating strips or magnetoresistors.

WO 99/42893 also discloses a tunable add-drop multiplexer. In order to tune the wavelength, the refractive index of the filter material is changed, for example by heating.

The known principles are unsuitable or too elaborate for producing an add-drop-continue function.

It is an object of the invention to propose an add-drop-continue module having little attenuation, as well as a filter which is suitable for its production and has a variable transmission characteristic. This module is also intended to permit reconfiguration of channels without causing interference.

It is another object of the invention to propose a circuit arrangement having cross-connect functionality, which allows simple allocation of dynamically assembled multi-wavelength bundles to different conductors. It is another object of the invention to propose a circuit arrangement having cross-connect functionality, which permits reduced complexity of the system. In this case as well, reconfiguration of channels is intended to be made possible without causing interference.

The object is achieved by a filter specified in claim 1, an add-drop-continue module specified in claim 6 and a "cross-connect module" for producing bundled

cross-connect functionality as claimed in the dependent claims. Variants of this module are furthermore specified.

Advantageous refinements are specified in the dependent claims.

The special advantage of the module, and of the circuit arrangement for producing bundled cross-connect functionality, is due to the filter whose frequency and attenuation can be varied. This not only makes it possible to select different channels: no optical switches are necessary for producing add-drop, drop-continue or cross-connect functions. Reconfiguration of the network can be carried out without interference to adjacent signals.

In particular, the invention is achieved by an optical filter, wherein a device (HE) is provided for adjusting the transmission response by means of a deliberate temperature change. The effect achieved by adjusting the transmission response through temperature changes is that the optical filter is non-destructively reconfigurable, which has never before been possible in the case of purely optical network elements except with expensive optical circuit technology (wavelength multiplexers, wavelength demultiplexers, space-switching matrices). In contrast to standard wavelength filters, the transmission attenuation can also be adjusted in addition to the resonant wavelength in the optical filter according to the invention.

In another preferred exemplary embodiment of the optical filter, at least two regions (B1, B2) in an optically transparent material, which have different temperature-dependent refractive indices n_1 (t) and n_2 (t), are essentially involved in the optical waveguiding and/or the filter action, and wherein the difference between the refractive indices n_1 (t) and n_2 (t) is at least approximately zero at one temperature within the temperature-controllable working range. The temperature-dependent difference in refractive index between two optical materials is hence influenced by the deliberate change of temperature. This exploitation of the

thermo-optical effect to influence the quality factor of the resonance is performed by adjusting the resonant wavelength λ_k and the transmission attenuation d for this wavelength. On the grounds of conservation of energy, the reflection factor is obtained directly from the transmission response in the ideal case. Energy components which are not transmitted must necessarily be reflected. The resonant wavelength λ_k is essentially influenced by the period Λ of the interfaces. The transmission attenuation is given essentially by (besides the grating length Z and the grating amplitude) the difference in refractive index $n_1 - n_2$.

The optical filter according to the invention is advantageously designed in planar technology. This facilitates integration into existing circuitry. The optical filter is furthermore preferably produced as a fiber grating. The difference in refractive index between two optical layers involved in the waveguiding is of essential importance in the case of fiber gratings as well. The principle employed here, namely to influence the transmission attenuation by a thermal refractive-index change, may therefore preferably be used in the case of such filters as well.

An optical filter is particularly preferably designed as a tunable band-stop filter. This facilitates the extraction of a frequency band. The latter is advantageous especially in purely optical telecommunications networks.

The tuning of the band-stop filter is particularly preferably carried out by mechanical pressure, tension or bending. By means of this, the wavelength to be filtered in the optical spectrum can be selected by exposing the band-stop filter to mechanical influence.

The invention is furthermore achieved by an add-drop-continue module having an optical filter according to the invention,

wherein the tunable optical filter (BSF) is arranged between a branching device (ZI1) for optical signals and an insertion device (ZI2, KO). By means of this, an add-drop-continue module can be constructed using an optical filter according to the invention. The signal is split in the branching device for optical signals, and one component is fed to the gate of the optical filter according to the invention. The component to be extracted is reflected and forwarded, whereas the component to be injected is inserted by the insertion device (ZI2, KO).

In another preferred add-drop-continue module of the present invention, a plurality of optical filters (BSF1 to BSFM) are arranged between a branching device (ZI1) for optical signals and an insertion device (ZI2, KO). By means of this, it is possible for a plurality of individually adjustable optical spectra to be extracted from the signal and, particularly preferably, to the injected or re-extracted via multiplexers and demultiplexers, respectively.

In another preferred add-drop-continue module of the present invention, circulators are provided as the branching devices (ZI1) and as the insertion device (ZI2). By means of this, the injection and extraction of the signals can be carried out using known hardware components. Triple circulators are preferably used for this. Quad circulators are particularly preferably used. It is also possible to use Mach-Zehnder structures.

The object of the present invention is particularly preferably achieved by an add-drop-continue device, wherein a plurality of series-connected add-drop modules of the present invention are provided. By means of this, it is possible to fulfill a very wide variety of circuit tasks within purely optical networks.

In another preferred drop-and-continue module having an optical filter according to the invention, the optical filter is connected downstream of a branching device for optical signals. By means of this, it is possible to produce the drop-and-continue functionality by using purely optical hardware components.

The invention is furthermore achieved by a cross-connect module which comprises at least one optical filter according to the invention. By means of this, it is possible to provide a cross-connect module in which the reconfiguration can take place non-destructively. The possibility of controlling the transmission response of the optical filter by deliberately changing the temperature allows the filter action of the optical filter to be suspended by the appropriate temperature selection. At this moment, the filter does not in any way interfere with adjacent channels since no reflection takes place. Tuning of the filter can now advantageously be carried out. When the optical spectrum is being changed, adjacent optical spectra are crossed without causing any effect on the signals that may likewise be transported in this circuit over these optical spectra. It is hence possible to select a new channel without thereby influencing, or even interfering with, the channels or the signal flow which need to be crossed in doing so. After the desired new spectrum or channel has been reached, the reconfiguration is completed by resetting the temperature in such a way that the filter action restarts. This is preferably done by returning the difference in refractive index ($n_1 - n_2$) to a magnitude greater than zero by the temperature change.

A preferred cross-connect module of the present invention comprises at least one add-and-drop module. By

means of this, it is possible to construct the cross-connect module from add-and-drop modules.

Another preferred cross-connect module of the present invention has at least one quad circulator and/or at least one Mach-Zehnder structure. By means of this, it is possible to reduce the number of circulators used.

A cross-connect device is preferably provided which contains a plurality of series-connected cross-connect modules of the present invention. By means of this, it is possible to cascade the circuit arrangements and hence interconnect even more lines.

In a preferred method of the present invention for the non-destructive tuning of a filter, the filter loses its filter characteristic as a result of a first temperature change, then the tuning of the filter is carried out, and then the filter regains its filter characteristic as a result of a second temperature change. This method permits non-destructive reconfiguration of purely optical network elements. The exploitation of the thermo-optical effect to influence the quality factor of the resonance of the filter makes it possible to adjust the filter, by a first temperature change, in such a way that it loses its filter characteristic. This is preferably done by adjusting the temperature-dependent refractive indices in such a way that the difference becomes zero. So long as the filter has been "switched off" in this way, the tuning of the filter can be carried out without influencing adjacent channels or channels which are crossed. Once the new channel has been reached, i.e. the filter has been tuned to the new optical spectrum, the filter is "switched on" again by a second temperature change. In doing so, the temperature is preferably changed in such a way that the refractive indices again have a predetermined difference.

By means of this, a method for the non-destructive reconfiguration of purely optical network elements, in particular of the filter according to the invention, is procured.

The optical filters of the present invention are particularly preferably used for the production of a circuit having add-and-drop functionality; and/or a circuit having drop-and-continue functionality; and/or a circuit having multicast functionality; and/or a circuit having dual-homing functionality; and/or a circuit having cross-connect functionality. Multicast is the deliberate linking of a plurality of selected receivers to one transmitter (also referred to as group call). Dual homing is the connection of one receiver via two different network elements and paths. By means of this, it is possible to provide purely optical network elements which have the functionalities referred to above and are at the same time non-destructively tunable or reconfigurable.

The invention and other advantageous features will be described in more detail with reference to exemplary embodiments.

Figure 1 shows an add-drop-continue module,

Figure 2 shows an add-drop-continue module according to the invention,

Figure 3 shows a variant of this add-drop-continue module,

Figure 4 shows a possible filter construction,

Figure 5 shows the transmission diagram of the band-stop filter,

Figure 6 shows the transmission diagram of the band-stop filter in the case of a drop-and-continue function,

Figure 7 shows an add-drop-continue device having a series circuit in which a plurality of add-drop-continue modules are connected together,

Figure 8 shows a variant for the simultaneous extraction/injection of a plurality of WDM channels

Figure 9 shows a standard optical cross-connect module (OXC) having optical n x n space-switching subunits,

Figure 10 shows a schematic representation of a cross-connect module in WDM-systems,

Figure 11 shows cascaded cross-connect modules,

Figure 12 shows a circuit arrangement according to the invention of a cross-connect module,

Figure 13 shows another circuit arrangement according to the invention of a cross-connect module.

The add-drop-continue module represented in Figure 1 has already been explained in the introduction to the description. The splitter SP and the optical switch SW may be omitted if a tunable filter is being used which has resonant attenuation, so that a specific component of the energy of an optical signal, for example half said energy, is reflected and the remaining component is forwarded via the second circulator.

Figure 2 represents such an add-drop-continue module. It contains a first circulator ZI1, a tunable filter BSF and a second circulator ZI2. The transmission frequency of the filter can be continuously altered. The module can therefore be used for a plurality of wavelengths.

The attenuation of the filter can be changed by deliberately controlling the temperature, so that one signal range D_k is reflected by the filter and branched off, and the other signal component C_k is transmitted. It is hence possible to switch between the add-drop function and the drop-and-continue function using the same element, without optical switches being required. Of course, no signal is inserted in the drop-and-continue function (represented in Figure 2).

Figure 3 represents a variant of the add-drop-continue module, in which the second circulator has been replaced by a coupler KO. Although this variant is lees expensive, the coupler has greater attenuation.

If only the drop-and-continue function is to be produced, the second circulator or coupler may of course be omitted in a drop-and-continue module.

Figure 4 represents a possible embodiment of the filter in planar technology. The filter consists of an optically conductive material, generally quartz glass, and is essentially formed by a first region B1 having a temperature-dependent refractive index n_1 (t), (t - temperature), in which the essential energy component of the light is guided, and a second region B2 having a different temperature-dependent refractive index n_2 (t) regions. Only non-essential components of the light are guided in other regions, the substrate SUB and the superstrate SUP. They are hence only non-essentially involved in the filter action. The interface between the two regions 1 and 2 presents a wave structure of period λ, which has been produced by suitable diffusion or mechanical processing (grating). In the known fashion, this geometrical structure has a wavelength-selective transmission and reflection response, which is represented in Figure 5.

The resonant wavelength λ_k is essentially determined by the period of the interface; the transmission attenuation is determined essentially by, besides the grating length and the grating amplitude, the difference in refractive index $n_1 - n_2$.

The resonant wavelength λ_K can be altered by mechanical pressure P (represented by dashes in Figure 5). If, for example, a wavelength multiplex signal

λ_1, λ_2 ... λ_N (the same notation is used here for the optical signals as for the wavelengths) is fed into the filter, then one specific wavelength λ_K will be reflected whereas all the other wavelengths will be forwarded with very little attenuation.

A heating element HE can be used to heat the filter, so that the filter action is reduced and the transmission attenuation is decreased. A drop-and-continue function may be produced by setting an attenuation value of about 3 dB, as can be seen in Figure 6.

When the system is being reconfigured, the intention is for different optical signals, which have different wavelengths, to be branched off. By using the filter described above, this can be done without interfering with adjacent optical signals (or adjacent multiplex channels). The filter action is firstly removed by heating, so that all signals are forwarded. Tuning to the new wavelength is then carried out by exerting a mechanical pressure corresponding to this wavelength and subsequent cooling in order to restore the filter function, so that a different optical signal is now transmitted. Control circuits (not shown here) can be used to perform very accurate adjustment. Peltier elements may be used as heating and cooling elements.

Owing to their thermo-optical mechanism, these wavelength filters still have relatively high inertia. It is, however, already realistic to expect switchover times of from 10 ms to 500 ms, which is usually acceptable in the case of reconfigurations which are carried out infrequently.

In order for a plurality of optical signals λ_K, λ_{K+1} to be branched off and injected, a plurality of these modules Z1, BSF1, Z2, Z3, BSF2, Z4 are connected in series according to Figure 7.

Figure 8 shows an add-drop-continue module ZI1, BSF1, BSF2, BSF3, ZI2, in which a plurality of band-stop filters BSF1, BSF2, . . . BSFM are interposed between two circulators. According to the number of filters, a plurality of optical signals λ_1 to λ_M are simultaneously injected or extracted. Individual signals can be branched off or injected by using a demultiplexer DMUX a multiplexer MUX.

It should also be mentioned that the band-stop filter may also be produced with a larger bandwidth. Instead of individual channels, it is then possible to extract and inject channel groups comprising adjacent channels.

Figure 9 shows a solution for a standard optical cross-connect (OXC) having optical n x n space-switching subunits. In this case, demultiplexers DMUX are connected via optical conductors to a space-switching subunit of dimension n x n, which are in turn connected to multiplexers MUX. An incoming optical multi-wavelength signal is decomposed by the demultiplexer DMUX into a single-wavelength signal. These single-wavelength signals are subsequently switched by using optical space-switching subunits of dimension n x n. The forward-switched single-wavelength signals from the various space-switching subunits then reach the multiplexer MUX, where they are recombined to form an output signal.

In the case of a circuit arrangement having e.g. 64 wavelengths per multi-wavelength signal and 4 bidirectional conductor, 64 space-switching subunits of dimension 4 x 4 are needed.

By means of this arrangement, it is possible to switch each single-wavelength signal of an incoming conductor to any desired output conductor.

Figure 10 gives a schematic representation of a cross-connect module having bundled cross-connect functionality in WDM systems. In this case, wavelengths 1 to n arrive on line 1. The wavelengths 1 to i and l to m on lines 1 and 2 are connected together, m describing the maximum number of parallel wavelength signals per fiber in the WDM system and i and l being dynamically variable numbers in the range $1 \leq i \leq l \leq m$. Similar considerations apply for lines 3 and 4. This connection is indicated by the solid stroke. The dashed lines respectively represent the connection between line 1 and line 3, and between line 2 and line 4, for the wavelengths i to j and k to l, where i, j, k, l are dynamically variable numbers in the range $1 \leq i \leq j \leq j \leq k \leq l \leq m$.

The dotted lines represent the connections between lines 1 and 4, and between lines 3 and 2, in which the wavelength bundles j to k are switched together, where i, j, k, l are dynamically variable numbers in the range $1 \leq i \leq j \leq j \leq k \leq l \leq m$.

Using this circuit arrangement, it is possible to interconnect wavelength bundles in WDM systems with a cross-connect functionality.

Figure 11 gives a schematic representation of cascaded cross-connect modules. By connecting circuits of Figure 10 in succession, it is possible to produce more comprehensive cross-connect functionalities in WDM systems. Two such circuits have been cascaded in Figure 11, but it is also possible to cascade other circuits and use them in double-star topology, star topology or in meshed networks.

Figure 12 represents a circuit arrangement according to the invention with bundled cross-connect functionality. Four

conductors L1 to L4 are represented, which can be interconnected together. Circulators ZI1 to ZI12 are furthermore provided. These are triple circulators. Optical filters according to the invention are furthermore provided as band-stop filters BS1 to BS6.

The way in which the circuit operates will be explained with reference to the division of the signals arriving on L2 according to the cross-connect functionality represented in Figure 10.

The incoming multi-wavelength signal on L2 is completely forwarded via the optical circulator ZI1, in the direction of the arrow, toward the next gate and encounters the optical band-stop filter BS1. This filter reflects the wavelength channels OCH i to l that are to be extracted, and the remaining channels are transmitted. In the same way, the wavelength channels i to l are extracted from the lines 1, 3 and 4.

The multi-wavelength signal (i to l) that is extracted on L2 is completely forwarded via the optical circulator ZI5, in the direction of the arrow, toward the next gate and encounters the optical band-stop filter BS3. This filter reflects the wavelength channels OCH j to k, and the remaining channels are transmitted. The multi-wavelength signal that is extracted from line 1 and forwarded to the circulator ZI6 is reflected from the same optical band-stop filter BS3. Conversely, the transmitted wavelength channels OCH i to j and OCH k to l are exchanged at the band-stop filter BS3. The same principle is used to process the wavelength bundles extracted from line 3 and line 4.

The multi-wavelength signal coming from the circulator ZI5 is fed via the circulator Z12 to the line L4. In a similar way, the multi-wavelength signals coming from the circulators ZI6, ZI7, ZI8 are fed to the appropriate line.

The band-stop filters BS1 to BS6 are of broadband design, so that they cover a plurality of wavelength channels. If one of the filter edges lies outside the wavelength spectrum, then this situation can be used to produce a high-pass or low-pass function. The selection of a wavelength bundle is made possible by the adjustment parameter f at the band-stop filter, which is labeled with the corresponding indices. The "neutralization" of the filter may preferably be performed during reconfigurations by means of the transmission attenuation d.

By using the optical filter according to the invention in this circuit arrangement, it is possible to extract variable complete wavelength bundles from a multi-wavelength signal.

Figure 13 represents a similar circuit arrangement to Figure 12, but in which the triple circulators have been replaced by quad circulators. By means of this, it is possible to replace the 12 circulators which were used in the circuit arrangement according to Figure 12 by 8 quad circulators. The circulators may also be replaced by Mach-Zehnder structures.

By means of this, simple allocation of selected multi-wavelength bundles to different multi-wavelength channels is possible. The complexity of the system is reduced, in comparison with cross-connect modules of the prior art according to Figure 9, to a commensurately greater extent when the number of parallel wavelengths that are to be extracted per conductor is high. In the case of a circuit arrangement having e.g. 64 wavelengths per multi-wavelength signal and 4 bidirectional conductors, the solution variant having space-switching subunits and de-/multiplexers requires 64 space-switching subunits of dimension 4 x 4, whereas only 6 band-stop filters need to be used in the circuit arrangements proposed in Figures 12 and 13.

Patent claims:

1. An optical filter for producing a drop-and-continue function, which has a wavelength-selective grating with temperature-dependent reflection and transmission characteristics, and which has a device (HE) for adjusting the temperature of the grating so that a specific signal component that is to be branched off is reflected by the grating and another signal component having the same wavelength is transmitted.

2. The optical filter as claimed in claim 1, characterized in that it loses its filter action as a result of a further temperature change.

3. The optical filter as claimed in claim 1 or 2, characterized in that at least two regions (B1, B2) in an optically transparent material, which have different temperature-dependent refractive indices n_1 (t) and n_2 (t), are essentially involved in the optical waveguiding and/or the filter action, and
in that the difference between the refractive indices n_1 (t) and n_2 (t) is at least approximately zero at one temperature within the temperature-controllable working range.

4. The optical filter as claimed in claim 3, characterized in that it is designed in planar technology.

5. The optical filter as claimed in one of the preceding claims, characterized in that it is designed as a tunable band-stop filter.

6. The optical filter as claimed in claim 5, characterized in that

its bandwidth is tuned to that of a transmission channel.

7. The optical filter as claimed in claim 5, characterized in that the bandwidth is tuned to the bandwidth of a plurality of adjacent transmission channels.

8. The optical filter as claimed in claim 5, 6 or 7, characterized in that the tuning is carried out by mechanical pressure, tension or bending.

9. An add-drop-continue module having an optical filter (BSF) as claimed in one of claims 1 to 8, characterized in that the tunable optical filter (BSF) is arranged between a branching device (ZI1) for optical signals and an insertion device (ZI2, K0).

10. The add-drop-continue module as claimed in claim 9, characterized in that a plurality of optical filters (BSF1 to BSFM) are arranged between a branching device (ZI1) for optical signals and an insertion device (ZI2, K0).

11. The add-drop-continue module as claimed in claim 9 or 10, characterized in that circulators are provided as the branching device (ZI1) and/or as the insertion device (ZI2).

12. An add-drop-continue device, characterized in that a plurality of add-drop-continue modules as claimed in claim 9, 10 or 11 are connected in series.

13. A drop-and-continue module having an optical filter (BSF) as claimed in claim 5, 6, 7 or 8, characterized in that the optical filter (BSF) is connected downstream of a branching device (ZI1) for optical signals.

14. A cross-connect module having a plurality of inputs and a plurality of outputs, characterized in that it comprises at least one optical filter as claimed in one of claims 1 to 8.

15. A cross-connect module having a plurality of inputs and a plurality of outputs, characterized in that it comprises at least one add-drop-continue module as claimed in one of claims 9 to 12.

16. The cross-connect module as claimed in claim 14 or 15, characterized in that the cross-connect module comprises at least one quad circulator as the branching device or as the insertion device.

17. A cross-connect device, characterized in that it comprises a plurality of series-connected cross-connect modules as claimed in one of claims 11 to 17.

18. A method for tuning the filter designed as claimed in one of claims 1 to 8 without interfering with transmitted signals, characterized in that the filter is adjusted in such a way, as a result of a first temperature change, that it loses its filter characteristic,

in that tuning of the filter to a predetermined new wavelength is then carried out, and

in that the filter is subsequently adjusted, as a result of a futher temperature change, in such a way that it regains its filter characteristic at the newly adjusted wavelength.

19. Use of an optical filter as claimed in one of claims 1 to 8, for the production of

a circuit having add-and-drop functionality and/or
a circuit having drop-and-continue functionality and/or
a circuit having multicast functionality and/or
a circuit having dual-homing functionality and/or
a circuit having cross-connect functionality.

FIG 1

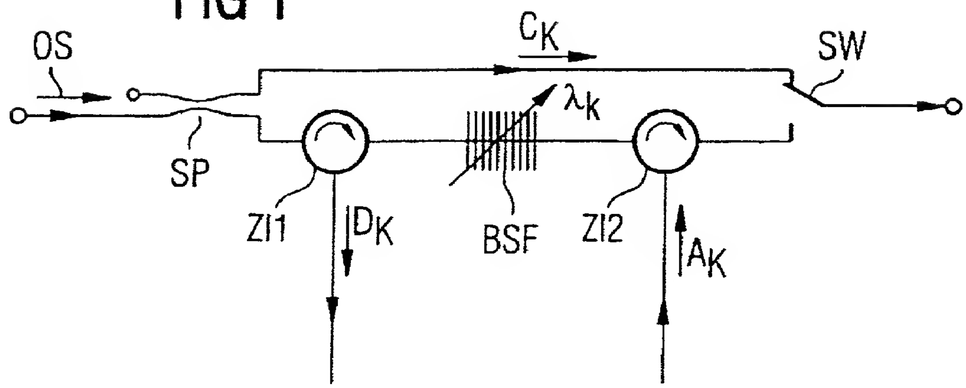


FIG 2

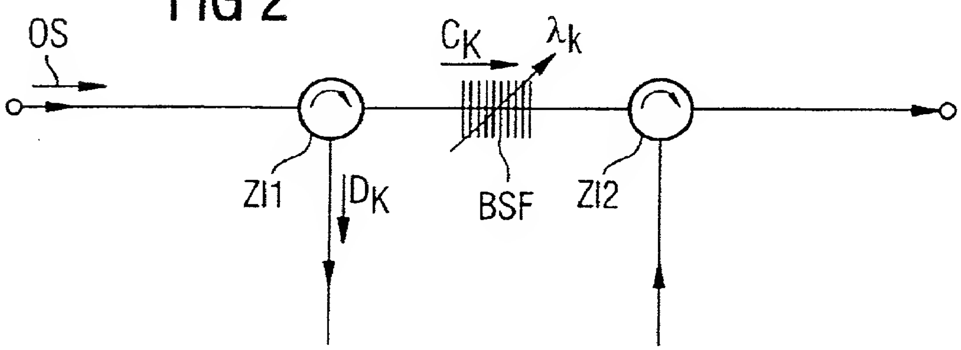


FIG 3

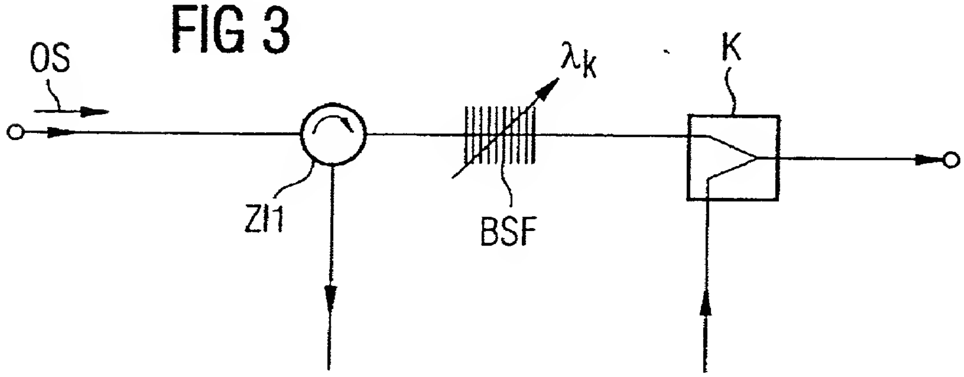


FIG 4

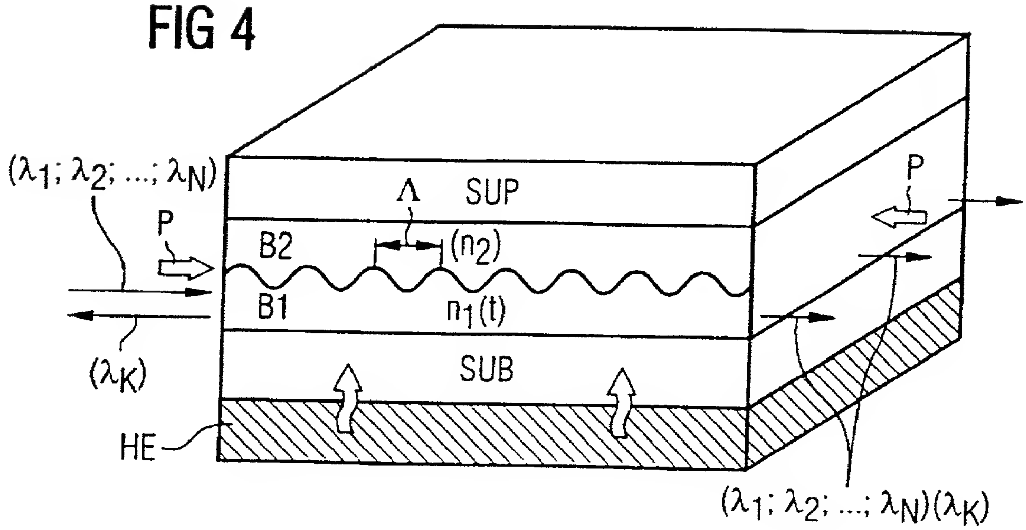


FIG 5

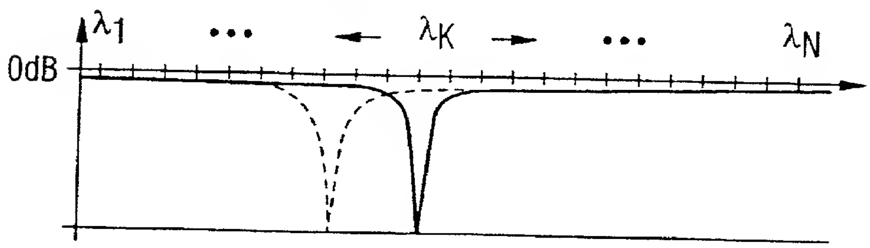


FIG 6

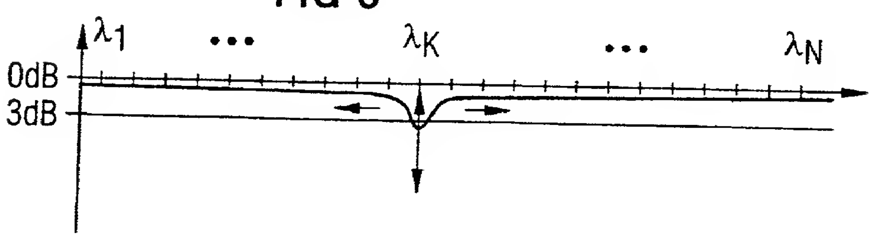


FIG 7

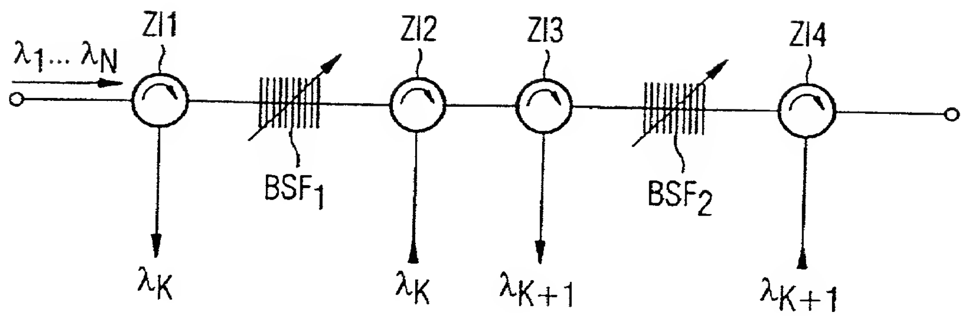

$\lambda_1 \dots \lambda_N$
ZI1
ZI2
ZI3
ZI4
BSF_1
BSF_2
λ_K
λ_K
λ_{K+1}
λ_{K+1}

FIG 8

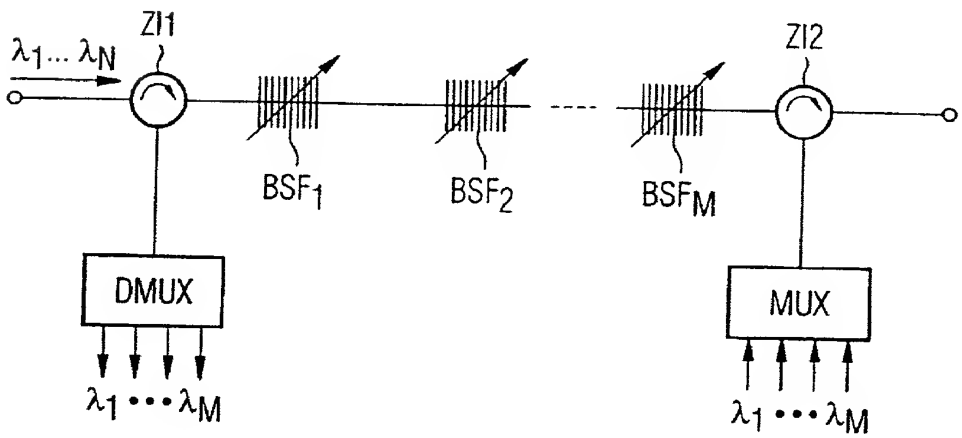

$\lambda_1 \dots \lambda_N$
ZI1
ZI2
BSF_1
BSF_2
BSF_M
DMUX
MUX
$\lambda_1 \cdots \lambda_M$
$\lambda_1 \cdots \lambda_M$

FIG 9

Prior Art

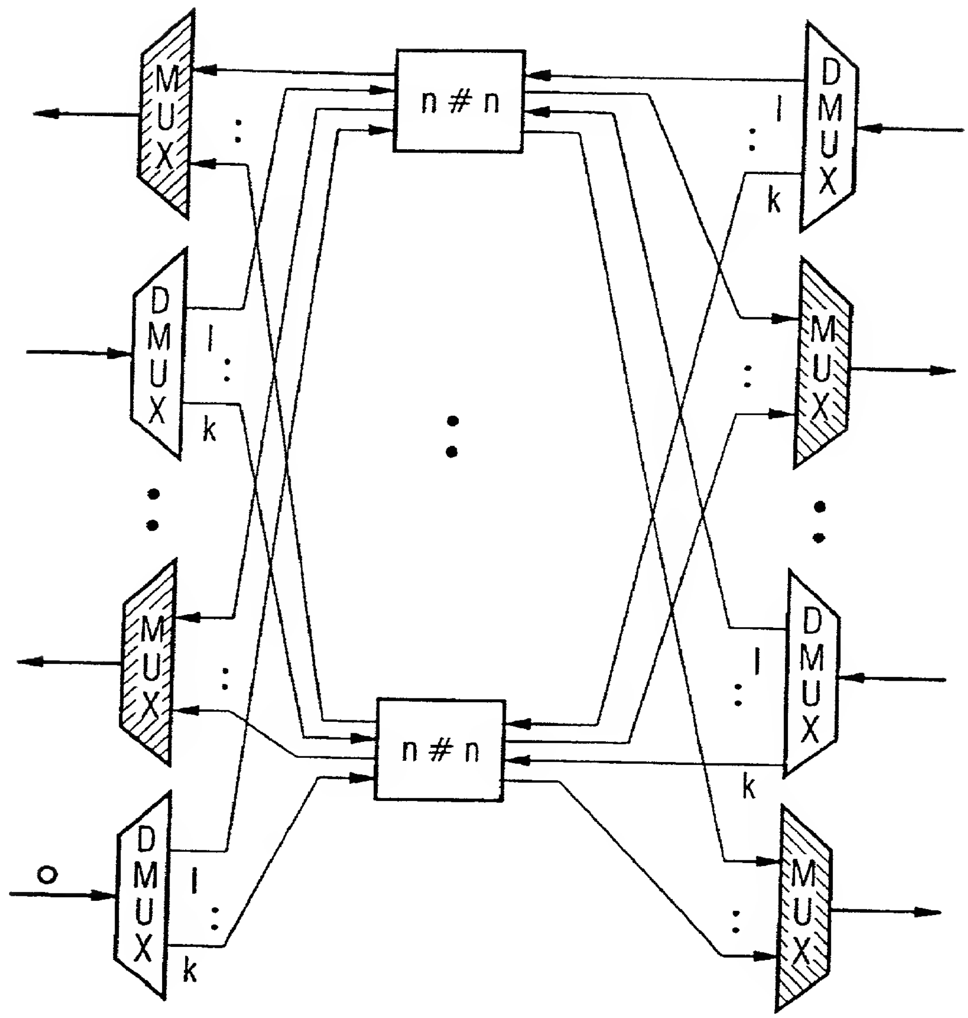


FIG 10

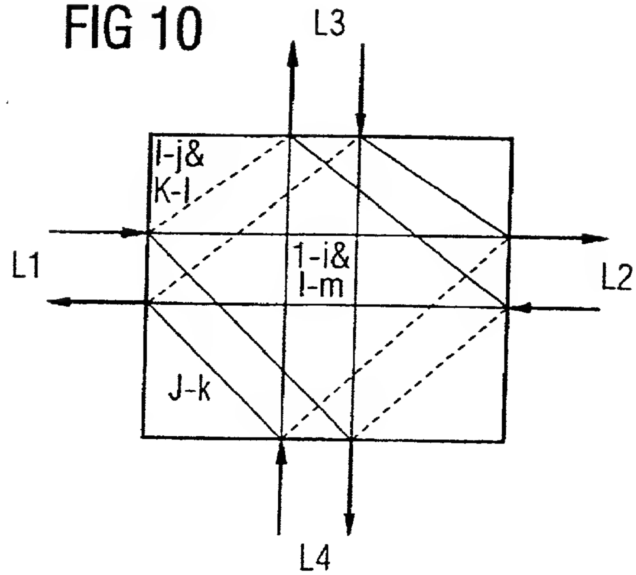

L3
I-j&
K-I
L1
1-i&
I-m
L2
J-k
L4

FIG 11

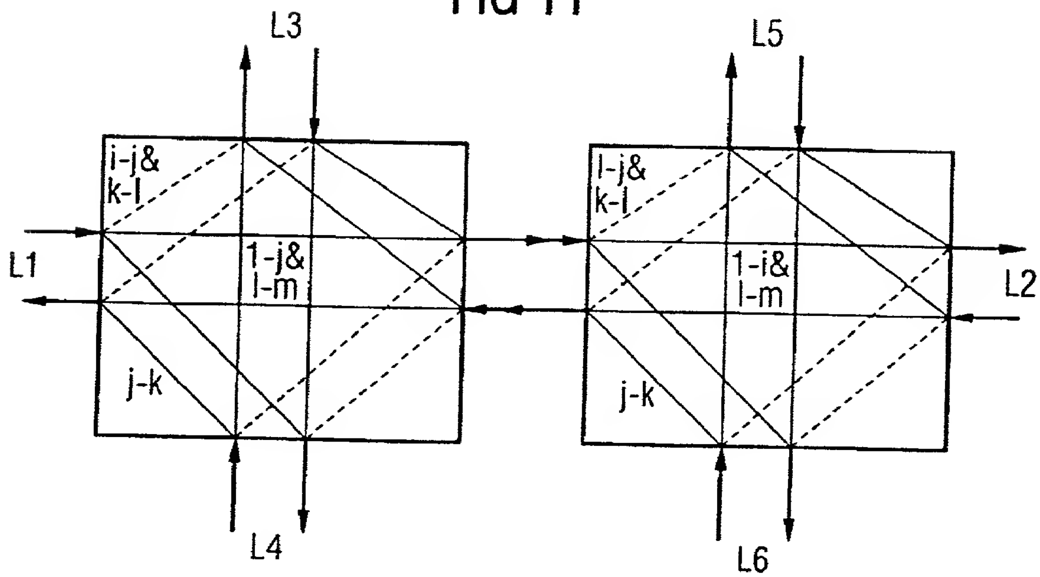
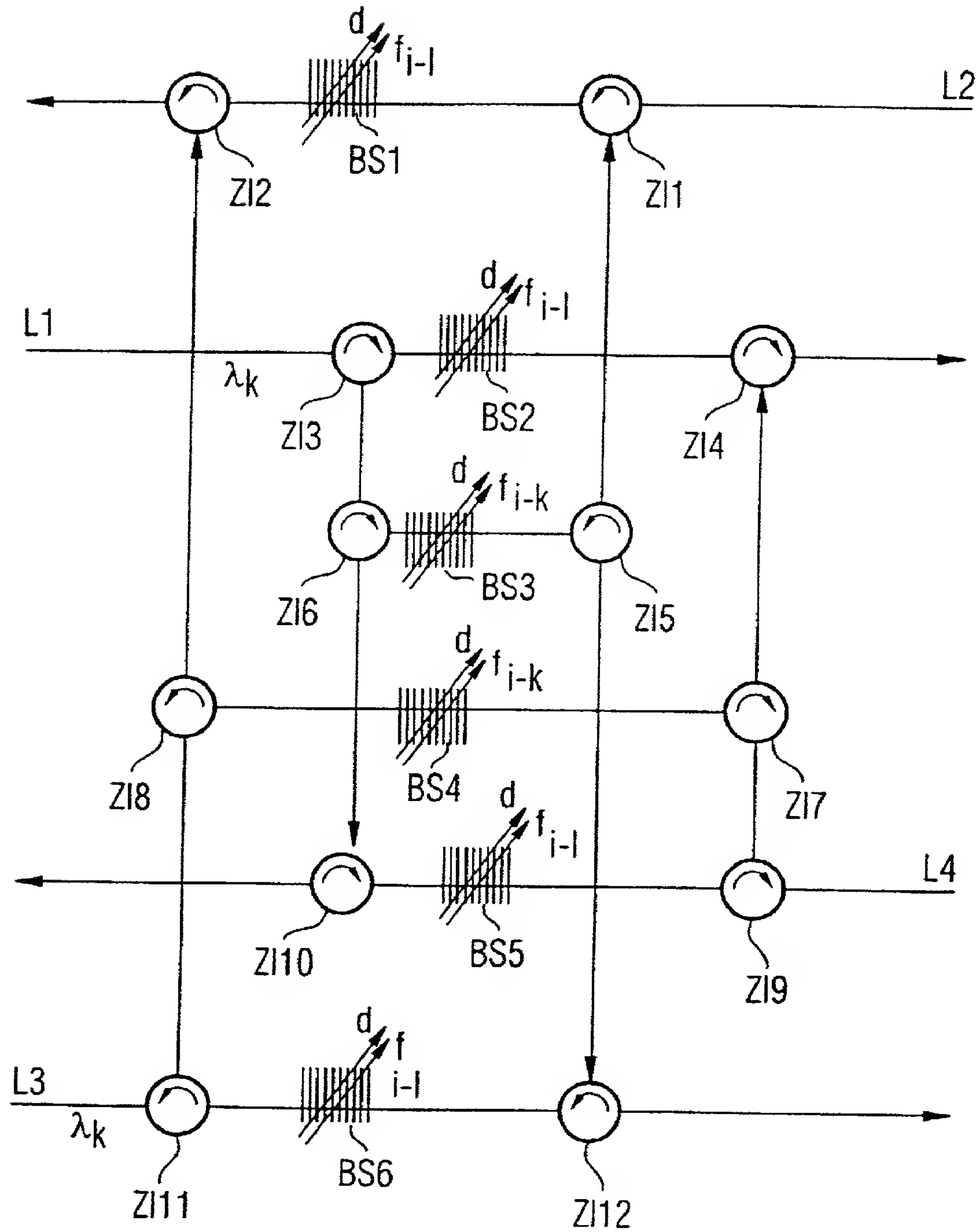
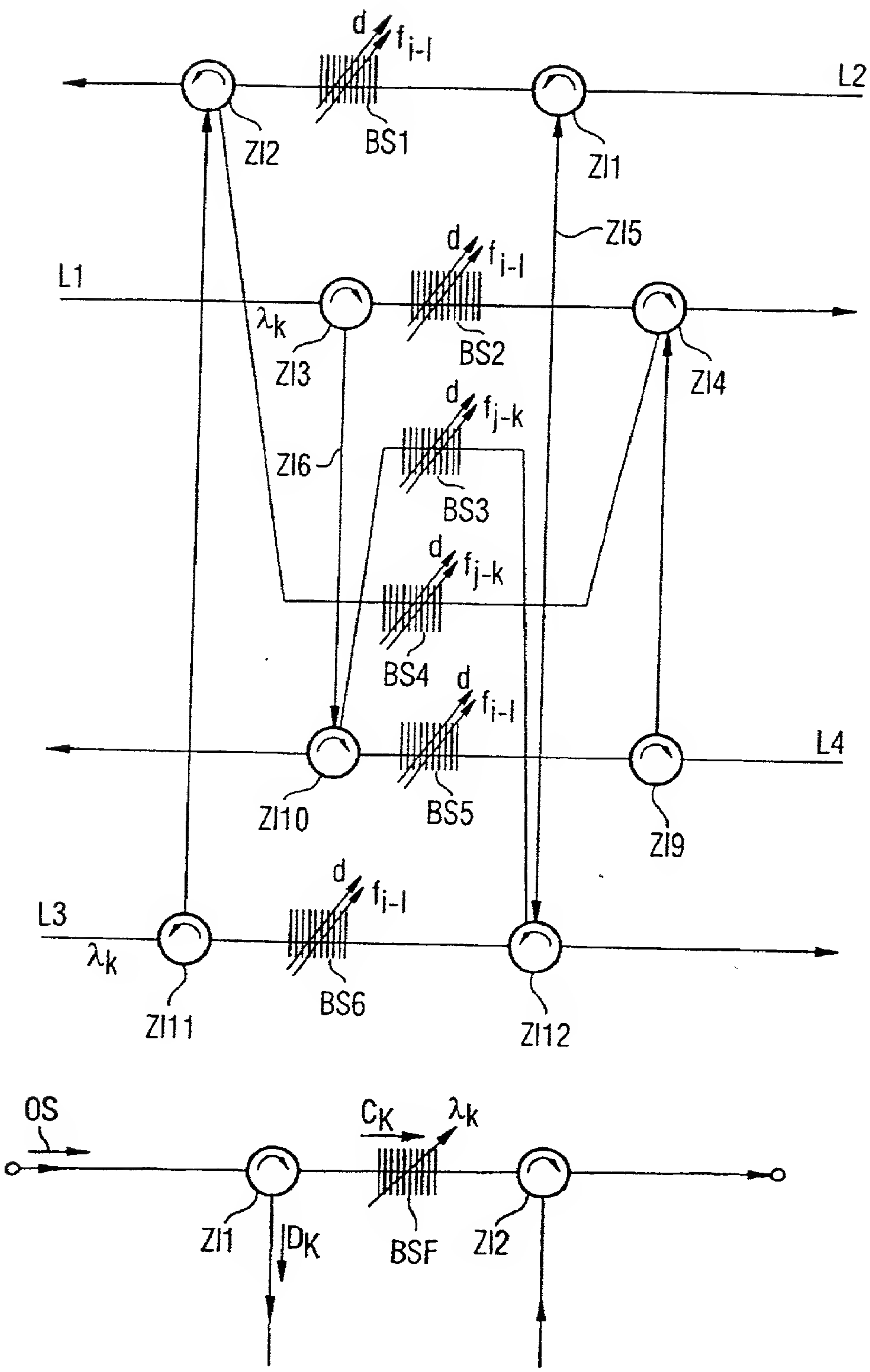

L3
i-j&
k-I
L1
1-j&
I-m
j-k
L4
L5
I-j&
k-I
1-i&
I-m
L2
j-k
L6

FIG 12



d
f_{i-l}
L2
BS1
ZI2
ZI1
d
f_{i-l}
L1
λ_k
BS2
ZI3
ZI4
d
f_{i-k}
BS3
ZI6
ZI5
d
f_{i-k}
BS4
ZI8
ZI7
d
f_{i-l}
L4
ZI10
BS5
ZI9
d
f
i-l
L3
λ_k
BS6
ZI11
ZI12

FIG 13



d
f i-l
L2
Zl2
BS1
Zl1
Zl5
d
f i-l
L1
λk
Zl3
BS2
Zl4
d
f j-k
Zl6
BS3
d
f j-k
BS4
d
f i-l
L4
Zl10
BS5
Zl9
d
f i-l
L3
λk
Zl11
BS6
Zl12
OS
CK
λk
Zl1
DK
BSF
Zl2

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

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Optisches Filter, abstimmbarer Add-Drop-Continue-Modul und Schaltungsanordnung für gebündelte Cross-Connect-Funktionalität

deren Beschreibung

(zutreffendes ankreuzen)

☒ hier beigefügt ist.

☐ am ______________ als
PCT internationale Anmeldung
PCT Anmeldungsnummer ______________
eingereicht wurde und am ______________
abgeändert wurde (falls tatsächlich abgeändert).

Ich bestätige hiermit, dass ich den Inhalt der obige☐n Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

____
____
____
____

the specification of which

(check one)

☐ is attached hereto.

☐ was filed on ______________ as
PCT international application
PCT Application No. ______________
and was amended on ______________
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Declaration and Power of Attorney For Patent Application

Erklärung Für Patentanmeldungen Mit Vollmacht

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dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

Optisches Filter, abstimmbarer Add-Drop-Continue-Modul und Schaltungsanordnung für gebündelte Cross-Connect-Funktionalität

deren Beschreibung

(zutreffendes ankreuzen)

☐ hier beigefügt ist.

☒ am 06. Oktober 1999 als PCT internationale Anmeldung PCT Anmeldungsnummer PCT/DE99/03227 eingereicht wurde und am ________ abgeändert wurde (falls tatsächlich abgeändert).

Ich bestätige hiermit, dass ich den Inhalt der obige☐n Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

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As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

____

the specification of which

(check one)

☐ is attached hereto.

☐ was filed on ________ as PCT international application PCT Application No. ________ and was amended on ________ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign appplications
Priorität beanspruchte

Priority Claimed

198 46 674.9	Germany	09. Oktober 1998	☒ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
199 40 302.3	Germany	25. August 1999	☒ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			☐ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhangig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

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German Language Declaration

VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschäfte vor dem Patent- und Warenzeichenamt: *(Name und Registrationsnummer anführen)*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

(13)

And I hereby appoint

Messrs. William E. Vaughan (Reg. No. 39,056); Robert M. Barrett (Reg. No. 30,142); Michael S. Leonard (Reg. No. 37,557); Patricia A. Kane (Reg. No. 46,446); Thomas C. Basso (Reg. No. P46,541); Robert W. Connors (Reg. No. P46,442); Troy A. Groetren (Reg. No. 46,442); Adam H. Masia (Reg. No. 35,602); Dante J. Picciano (Reg. No. 33,543); Amy J. Gast (Reg. No. 41,773); Timothy L. Harney (Reg. No. 38,174); Renato L. Smith (Reg. No. 45,117); and Alan L. Barry (Reg. No. 30,819)

Telefongespräche bitte richten an: *(Name und Telefonnummer)*

Direct Telephone Calls to: *(name and telephone number)*

(312) 807-4292
Ext. ______________

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Send Correspondence to:

William E. Vaughan
Bell, Boyd & Lloyd
P.O. Box 1135
Chicago, IL 60690-1135

Voller Name des einzigen oder ursprunglichen Erfinders:	Full name of sole or first inventor:
1-00 STOLL, Detlef	
Unterschrift des Erfinders / Datum: D. Stoll / March 8th 2001	Inventor's signature / Date
Wohnsitz: Boca Raton, Fl 33496	Residence
Staatsangehörigkeit: Bundesrepublik Deutschland DEX	Citizenship
Postanschrift: 6503 N Militay MLL #4100	Post Office Addess
Boca Raton, Fl 33496 United States of America	
Voller Name des zweiten Miterfinders (falls zutreffend):	Full name of second joint inventor, if any:
2-00 BOCK, Harald	
Unterschrift des Erfinders / Datum: Harald Bock / 08/03/01	Second Inventor's signature / Date
Wohnsitz: D-86150 Augsburg, Germany DEX	Residence
Staatsangehörigkeit: Bundesrepublik Deutschland	Citizenship
Postanschrift: Hinterer Lech 36	Post Office Address
D-86150 Augsburg Bundesrepublik Deutschland	

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).

3-00

Voller Name des dritten Miterfinders: LEISCHING, Patrick	Full name of third joint inventor:
Unterschrift des Erfinders [illegible] Datum 9.2.2001	Inventor's signature Date
Wohnsitz D-81247 München, Germany	Residence
Staatsangehorigkeit Bundesrepublik Deutschland DEX	Citizenship
Postanschrift Fasanenstr. 18	Post Office Address
D-81247 München Bundesrepublik Deutschland	

4-00

Voller Name des vierten Miterfinders (falls zutreffend): SCHEERER, Christian	Full name of fourth joint inventor, if any:
Unterschrift des Erfinders [illegible] Datum 23.3.01	Inventor's signature Date
Wohnsitz D-81375 München, Germany DEX	Residence
Staatsangehörigkeit Bundesrepublik Deutschland	Citizenship
Postanschrift Ringstr., 4	Post Office Address
D-81375 München Bundesrepublik Deutschland	

5-00

Voller Name des fünften Miterfinders (falls zutreffend): STORTZ, Gerhard	Full name of fifth joint inventor, if any:
Unterschrift des Erfinders Gerhard Stortz Datum 2.3.01	Inventor's signature Date
Wohnsitz D-85586 Poing, Germany DEX	Residence
Staatsangehörigkeit Bundesrepublik Deutschland	Citizenship
Postanschrift Franz-von-Defregger-Str. 2 a	Post Office Address
D-85586 Poing Bundesrepublik Deutschland	

Voller Name des sechsten Miterfinders (falls zutreffend):	Full name of sixth joint inventor, if any:
Unterschrift des Erfinders Datum	Inventor's signature Date
Wohnsitz	Residence
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).